THE CALCULUS OF WAR: THE ROLE AND USE OF QUANTITATIVE DECISION AIDS AT THE TACTICAL LEVEL OF WAR

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

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The current command estimate process used by the U.S. Army is largely personality driven. The desires and vision of the commander serve as the primary forcus of this process. While this relationship is functional for the U.S.Army, more attention needs to be given to the physical aspects of land warfare - most of which are quantifiable with simple decision aids. The thesis traces the use of quantitative decision aids through history to develop the schools of thought that impact on the issue. It then isolates several different quantitative decision aids, and then uses them in three case studies to demonstrate their utility to the tactical decision maker. Finally, the thesis explores some some problems with the current contributions of Operations Research to tactical decision making.

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ABSTRACT

The Calculus of War: The Role and Use of Quantitative Decision Aids at the Tactical Level of War, by MAJ Kevin B. Smith, USA, 129 Pages

This study investigates the utility of quantitative tools as decision aids at the tactical level of war. It seeks to address how the U.S. Army may achieve the proper balance between the physical and moral forces of battle during the command estimate process.

The history of combat decision making reveals two primary schools of thought. One holds that man is the decisive power on the battlefield, while the other maintains that many battlefield phenomena are quantifiable. Both schools of thought have failed when misapplied, and both have succeeded when applied in balance with the other.

The study uses the lessons from three case studies to adjudicate the conflict between these divergent points of view. This study concludes that both the school of moral force and the school of quantification must be in balance to fully realize a unit's combat power. The study makes recommendations about how to revise the Army's approach to Operations Research and Systems Analysis (ORSA).

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CHAPTER ONE

THE CALCULUS OF WAR

> Every deliberate act in war requires a fixed time for its commencement, and a fixed period, and an appointed place . . . the neglect of any one of them will ruin the whole design.[1]
>
> Polybius

> The general who wins a battle makes many calculations in his temple before the battle is fought. The general who loses a battle makes but few calculations beforehand. Thus to do many calculations leads to victory . . . by attention to this point . . . I can foresee who is likely to win or lose.[2]
>
> Sun Tzu

> The imitation of the ideal arts was quite out of the question, because . . . laws and rules . . . are perpetually undermined and washed away by the current of opinions, feelings and customs.[3]
>
> Clausewitz

Introduction

Few leaders in history have excelled at consistently and effectively matching military means to their desired ends. Yet, most pursued methods aimed at reducing the uncertainty of battle, at least in part through the use of some sort of battle calculus. This thesis explores the utility of quantitative tools as decision aids on the tactical battlefield.

Opposing viewpoints on the use of calculations as decision aids in war tend toward extremes. On the one hand is the romantic western image of the warrior--the leader able to sway battles by the power of his own will. On the other is the dogmatic, emotionless leader who feels compelled to calculate each and every variable before a decision is reached. These two extremes are so far apart that little, if any, happy medium is found. The purpose of this thesis is to explore the nature and utility of calculations as decision aids in the prosecution of war at the tactical level. In so doing, I seek to find a common ground, a point where the friction and unpredictability of man, and the inviolate Newtonian physics of machines meet and potentially coexist in harmony. Without such a joining point, it can be argued, the conceptual framework of our understanding of warfare is dangerously incomplete.

The Nature of the Problem

Warfare encompasses three broad areas of knowledge. Human behavior is the first, and perhaps the least understood of the three areas. Decades old, yet still at issue are the theories of the behavioral sciences. Physics is the second area--the rigidly predictable performance of machines. Lastly, but certainly not least, is the environment in which man and his machines clash with other men, and other machines. One problem in resolving the issue of calculation in war is the fact that our knowledge of these three areas ranges from abstract theories to concrete physical laws. This causes many professionals to discard quantitative methods and rely solely on professional judgment and visceral feelings as their primary decision making tools.

Direction of the Research Effort

The focus of this paper is to examine quantitative methods of conceptualizing battlefield phenomena, and examine their use as decision making aids. This thesis will first trace the use of quantitative methods as decision aids through history to determine the dominant schools of thought. The thesis will then apply simple quantitative tools to several case studies to demonstrate how quantitative aids could have helped (or hindered) commanders to better visualize battlefield dynamics. An analysis of these case studies will help define what utility quantitative tools have on the modern battlefield, if any.

Thesis Research Question

The primary research question of this thesis is to determine if quantitative decision making aids have utility at the tactical level. In order to answer the primary question, a number of secondary questions must first be explored and answered in this thesis:

1. **Which battlefield phenomena are subject to quantitative examination?** The thesis must determine those battlefield phenomena that are subject to accurate prediction by quantitative methods. The thesis will demonstrate the qualitative improvement in decision making (if any) that the use of quantitative aids provides.

2. **Which battlefield phenomena defy quantification?** The thesis must determine if the underlying assumptions of the 'moral force' school of thought (man as the decisive force) have validity, and which battlefield phenomena defy quantification because of man's impact.

Problems Associated with the Research

There are three major problems to overcome: the negative connotations associated with calculations in the U.S. Army; the lack of accepted research dealing with quantified human performance in combat; and arranging the results of this thesis into a format usable and accepted as a planning tool in the field.

Assumptions

This thesis uses the following assumptions:

1. That calculation of some battlefield phenomena is a prerequisite to success.

2. As our Army decreases in size, the need to more accurately fit means to ends at the tactical level will become more important.

Definition of Key Terms

What are Quantitative Methods?

Quantitative methods are analytical methods adopted and adapted from mathematics and statistics. They are useful in problem solving, decision making, and policy formulation. The quantitative methods of concern in this thesis generally involve the creation of a model - a representation of the relationships that define the condition under study. A model may be a set of equations, a computer program, or another type of representation using verbal statements or physical objects such as diagrams, maps or pictures. Quantitative methods employ three classes of models:

1. Deterministic models, in which the variables can take on only definite values, such as 2x2=4.

2. Probabilistic (or stochastic) models, in which the variables can take on a range of values, and the determination of the exact or mean value involves risk; an example would be weather forecasting.

3. Heuristic models, which represent a systematic approach to the solution of the problem based on trials, experiences, or experiments but with no assurance of a perfect solution.[4]

What is tactical utility?

In this context, quantitative decision aids have tactical utility when they help define the tactical problem or issue, aid in selecting the best solution, and measure the implementation of the selected solutions.[5] In practical terms, quantitative decision aids have utility when they not only provide a qualitative improvement over decisions based on 'gut feelings', but are also accepted and used by the tactical community.

Limitations

The limitations to the thesis are driven by the limitations of the average tactical decision maker. First, any quantitative method must be simple to visualize. More variables in a model probably equates to more confusion in the field. Second, any quantitative aid must be easy to use. Complex mathematical formulae are likely to be quickly discarded in battle. Third, the quantitative decision aids explored in this thesis must provide a qualitative improvement in decision making.

Delimitations

This thesis will concentrate on battlefield phenomena found in mid-intensity, conventional warfare. Further, this thesis will focus primarily at the tactical level of war from corps down to brigade. Finally, this thesis will not formally address the psychological aspect of war, other than to examine it as a part of aggregate unit performance.

Significance of the Study

The intent of this study is to convince the tactical community that quantitative methods have a useful place in decision making. Ideally, this study should demonstrate that quantitative methods should serve as the physical basis upon which the tactical decision maker constructs the humanistic or creative component of war. This realization can spark the tactical community to pursue the appropriate integration of quantitative decision aids into the tactical thought process.

Conclusion

The utility of quantitative methods as tactical decision aids is by no means widely accepted. Tactical decision makers often rely on experience and intuition to make a majority of battlefield decisions. This thesis will attempt to illustrate the primary schools of thought surrounding this issue, determine quantitative aids appropriate for a set of major battlefield functions, and then apply these decision aids to a series of historical case studies. This will serve to help define the utility of quantitative aids and, conversely, illuminate battlefield phenomena that are not subject to quantification.

CHAPTER TWO

HISTORICAL PERSPECTIVE

Introduction

This chapter provides a historical perspective to familiarize the reader with the use of calculations as decision aids, the identification of the major schools of thought concerning calculations, refinement of both the research question and direction of the research effort.

Antiquity

From the time of Archimedes, history is filled with examples of military commanders--and industrial managers--who used various rudimentary forms of calculations to improve their effectiveness.[6] From antiquity, ". . . people were perfectly aware of the importance of numbers as a variable of military conflict. Indeed there are many historic battles where the sources record (however inaccurately) the number of combatants and virtually nothing else. Weapons, too, were sometimes analyzed in quantitative terms."[7] Apart from the age-old use of arithmetic for the computation of logistics requirements[8], science became actively engaged in the areas of ballistics, engineering, explosives, mechanics, and metallurgy at the beginning of the Renaissance.[9] In the 14th Century, Leonardo Da

Vinci would conduct rudimentary investigation into the performance of armaments -- "I ask if a crossbow sends a bolt weighing two ounces a distance of four hundred braccia, how many braccia will it send one of four ounces?"[10] The beginning of the Age of Discovery saw logic and scientific process applied increasingly to a great variety of human activity. Barely two hundred years later, applied military sciences had developed to the point where the first gunnery schools in Spain could comfortably analyze a weapon's performance in terms of range, rate of fire, and lethality against various types of targets.[11]

By the 18th century, the conduct of war had largely passed from the hands of the mercenary armies. More and more, armed forces became standing professional bodies, led by officers often considered more public servant and less nobility.[12] Along with this general trend, professional schools sprang up around Europe -- the first being the Ecole Militaire, established by Louis XV in 1751. Significantly, one of the most extensive topics taught in that school was mathematics, since that topic figured so heavily in engineering, gunnery and navigation. Of the different mathematic areas that could be studied to good effect, the dean of the Ecole settled upon a curriculum primarily composed of algebra, since it ". . . trains the mind and forms the judgment."[13]

The 19th Century

The 1800's began with a student of the Ecole, Napoleon, raising a new army to defeat Austria, and ended roughly with Count von Schlieffen's plan for Germany's anticipated two-front war with

Russia and France. Between these two signal points, the industrial age allowed man to use machines more and more to extend his own effort on the battlefield. This, in turn, provided the means to move more men, launch more munitions, and fight across greater distances. Managing the ever-growing complexities of war would eventually overcome the mental powers of a single general -- even one as brilliant as Napoleon -- and, eventually, require dedicated general staffs.

While Napoleon's battles and conquests are familiar to most, his command estimate process remains obscure. Napoleon often took the field with 1-200,000 men and several hundred cannon. Although Napoleon operated a massive and sophisticated system of depots and trains, his army normally fed off the surrounding countryside while on the march, requiring him to transport mostly powder and ball.[14] The simplicity of the technology, and the correspondingly simple nature of logistics allowed the command estimate to be calculated by one man -- Napoleon.

Napoleon's estimates were ". . . designed with one single ultimate end in view -- the procurement of a favorable battle situation at the earliest possible moment."[15] Towards this end, Napoleon's personal effort concentrated on the essentials of movement and logistics. To prepare for the Emperor's feverish calculations, his chief of staff, Berthier, would arrive early and establish the situation map, complete with ". . . information supplied by the Statistical Bureau concerning the enemy . . . the Army's own positions and strength . . . special closets containing carefully arranged information . . . and four secretaries."[16] Napoleon would eventually arrive and begin the estimate process with an assistant. Bacler d'Albe:

> Together they would crawl over the surface of the map, pressing in more pins, and cursing or grunting when their heads or hindquarters came into collision. Bacler would also be entrusted with important calculations of time and distance. He led a dog's life; the Emperor's first and last command on every day spent on campaign was invariably "send for d'Albe".[17]

From this twice-daily manual calculation of time, distance, routes used, and the nature of the countryside, Napoleon estimated the quantity of rations, animal fodder and wagons required for the Army's movement.[18] Often, this estimate process enabled Napoleon to predict the location of the decisive battle several weeks before it took place.[19] It is quite significant that Napoleon trusted this process to no one but himself -- perhaps, as Martin van Creveld has noted, because ". . . nobody but him could have made such a system work."[20] The calculations that brought hundreds of thousands of soldiers together from different directions were ". . . carried in his capacious head."[21] In the end however, an older, perhaps less-energetic Napoleon faltered under the stress of his custom one-man system. It is very likely, therefore, that Napoleon's system of command -- his calculations and estimate process -- marked the upper boundary of what a single man could accomplish. Although the command estimate would change in the future, elements of the Napoleonic command estimate process -- specifically movement and logistics calculations -- would remain essentially intact to the present day.

As technology and the industrial revolution accelerated through the 1800's, military units found themselves equipped with, and dependent upon, more machines of every type. This proliferation of technology served to complicate the number and nature of the data that had to be analyzed in order to predict movement and logistics, extended the need for calculation far beyond the ability of a single man, and multiplied the scope and scale of management functions across the battlefield. In short, machines vastly extended man's physical effort, but their large-scale use required a substantial extension of man's intellect as well. Without computers, an increase in intellect could only be found in smarter and larger staffs. An alternative course of action simply did not exist, since any army dependent upon machines could not ". . . be mismanaged without ceasing to function, completely, and much more quickly than either horses or men."[22]

An example of the Prussian military's familiarity with the use of numbers to represent combat phenomena during the mid 1800's comes from an examination of the war game Kriegsspiel. Written by 1st Lieutenant von Reisswitz in 1824, the Prussian Army used this gaming system in its original form until the 1870's, and in modified form until the mid 20th Century.

Kriegsspiel was a two-sided war game played on a map with a recommended scale of 1:8,000. The map showed the same topographic features that today's maps show -- slope, hydrology, roads, towns, vegetation, and obstacles. The game was divided into two-minute turns and each player was ". . .only allowed to move . . . as far on the map, in each move, as they would be able to go in reality in two minutes."[23] In crafting the rules of the game, von Reisswitz demonstrated a mature understanding of battlefield dynamics in a variety of numerical tables.

Lt. von Reisswitz also included a detailed section on artillery and infantry weapons that incorporated munition type, range, rate of fire, and target effect -- indicating that the military use of numbers had made substantial progress from Da Vinci's simple linear reasoning on crossbow projectile weights and ranges.

Also unique to Kriegsspiel was a reliance on an older, more experienced referee to adjudge the moral condition of troops. Depending upon the judgment of the referee, Kriegsspiel infantry started as 'fresh' and then degraded under fire from 'shaken' to 'repulsed' and, finally, to 'defeated.'[24] The referee would roll a different die to adjudicate engagements in each condition. In Kriegsspiel, one notes a Prussian readiness to represent many physical battlefield phenomena with mathematical models, and the recognition that some phenomena -- especially those unique to men under fire -- needed 'special handling' through a referee's judgment and further randomization through the use of different dice for different moral conditions.

It is uncertain which came first -- a numerical concept of battlefield phenomena, or a widely accepted game containing valid mathematical representations of combat. It is unlikely that a war game used for decades of army-wide training would either present game-unique concepts, methods foreign to the army as a whole, or deliberately present erroneous information. In creating the game, von Reisswitz used empirical data and heuristics commonly known to the officers of the era, and ". . . players did not need to be completely familiar with the detailed rules of the game . . . any officer could take part after a brief explanation."[25] The existence of Kriegsspiel suggests that the conceptualization of war through numbers was a relatively mature practice by at least the mid 1800's. Since Kriegsspiel was used to train Prussian officers for the next 50 years, it is highly likely that many officers subsequently used the game's conceptual framework to plan for and conduct actual battles. It is also likely that the staffs and general staffs of the era used similar gaming techniques to plan for larger-scale operations.

By the mid-1800's, the German General Staff had organized itself into functional Departments: the Departments of Foreign Armies East and West (Intelligence), the Central Department (Organization, Training, and Mobilization) and the Railway Department (Deployment and Movement).[26] By the end of the 19th century, the General Staff would expand further still because of the industrial revolution, and scientific spirit of the 1800's--which caused many to regard war as a science, ". . . and consequently as subject to systematic study and analysis in the same way that physics or chemistry is."[27] This attitude of 'science over art' continued to grow in the General Staff to the point where the Schlieffen plan could envisage the ". . . destruction of France in precisely forty-two days of pre-planned maneuvering."[28] Choice of words in this quote implies that the German General Staff accepted and used mathematical constructs of war which by now precisely calculated the effect of human friction in combat. This tendency for staffs to calculate away the effect of human error is by no means confined to either Germany or to the 19th century.

While von Schlieffen predicted victory in 'exactly 42 days,' other theorists, using a quantitative approach, were predicting immediate disaster at the beginning of the next war. One such theorist was Jean de Bloch, a Warsaw banker undoubtedly familiar with the numerical techniques of financial estimates. In his book, The War of the Future, published seventeen years before W.W.I, he used extensive calculations to predict that:

> At first there will be increased slaughter -- increased slaughter on so terrible a scale as to render it impossible to get troops to push the battle to a decisive issue. They will try to, thinking that they are fighting under the old conditions . . . . The war, instead of being a hand-to-hand contest in which the combatants measure their physical and moral superiority, will become kind of a stalemate, in which, neither army being able to get at the other, both armies will be maintained in opposition to each other, threatening each other, but never being able to deliver a final and decisive attack . . . . That is the future of war.[29]

De Bloch's The War of the Future departed from the conventional wisdom of the day in several important respects. First, it represented the most complete contemporary example of what we would consider today to be operations research (OR). Until de Bloch synthesized the test range data and individual theories of the materiel developers, no coherent argument could be made against the moral force school of thought, symbolized by du Picq. Up to this point, simple quantitative tools had been used to calculate only the movement and supply of armies. The Prussians had, as discussed earlier, already adopted the Kriegsspiel war game as a means of conceptualizing combat phenomena, but the tables and rules of the game were derived empirically -- not theoretically. What Bloch offered was a second school of thought -- a theoretical method to predict the outcome of future combat based on quantitative data. Many professional soldiers thought de Bloch to be perfectly mad, but he predicted the initial shape of the W.W.I battlefield with amazing accuracy.[30]

Second, Bloch offered a rational method of producing what we would term today a net strategic assessment. Using statistics on mobilization potential, industrial potential, social factors, and economics, de Bloch wove a convincing argument for the quick collapse of any future 'total' war. Of course, in this effort, he turned out to be wrong -- largely because of the difficulty in isolating causal factors in economic analysis and the creative ability of governments to finance a war footing.

Although de Bloch accurately predicted the opening slaughter of W.W.I, he overlooked the unique 'measure-countermeasure' nature of war. In this case, the 'measure' was the increased lethality of the battlefield towards human flesh. As J. F. C. Fuller pointed out, de Bloch missed the 'countermeasure,' which eventually arrived in the form of the tank.

While both attempted to quantify the battle in its entirety. the comparison between de Bloch and von Schlieffen (precise victory versus certain disaster) illustrates the widely different estimates that can be generated with different mathematical models of the same phenomenon. This is one reason why the quantitative approach that includes man as a numerical entity has never been fully accepted by professionals to this day.

Both von Schlieffen and Napoleon used calculations and command estimates for the same ends -- to ensure victory. At the beginning of the century, Napoleon commanded several hundred thousand foot-mobile soldiers that moved like columns of locusts across the face of Europe. He could claim responsibility for an estimate process performed on hand and knee across the floor of any convenient farmhouse -- a process that could (on a good day) move and supply his own army and look accurately into the near future. A century later, Count von Schlieffen faced a two-front war involving millions of soldiers, 65,000 miles of rail lines,[31] over one million telephone and telegraph stations,[32] and thousands of cannon that consumed ammunition at a prodigious rate. His estimate process required 239 General Staff Officers,[33] and a period of about a year for each iteration of his plan.[34] If anything, this comparison illustrates the simple axiom that as any task gets bigger and more complex, it takes more information and effort to manage it efficiently.

By the end of the 19th Century, therefore, the use of numbers and calculations to at least qualitatively assist the decision making process was widely accepted, and included the following:

- Calculations concerning logistics requirements.
- Calculations concerning movement of forces by foot and horse over terrain of varying difficulty, and estimates of large-scale rail movements.
- Calculations estimating the effect of each type of munition based on volume, range and target type.
- Calculations to arrive at force ratio estimates, and loss estimates.
- Calculations to determine the speed of intelligence, and command and control data.

Some military professionals from this era took note of the increased influence of numbers in military decision making and voiced strong opinions against this trend. In 1870, Ardant du Picq argued that

> . . . we shall better understand (the masters) and the great examples they have left behind . . . . We shall learn from them to distrust mathematics and materiel dynamics as applied to battle principles. We shall learn to beware of the illusions drawn from the range and the maneuver field.[35]

As du Picq demonstrates, the French General Staff of the late 1800's reflected a different view on the quantification of men in combat. Inheritors of Napoleon's legacy, the French were quite aware of the use of rail movement calculations to mobilize against the Prussians. Like other staffs, they knew the simple math of logistics and movement planning and the meaning of weapons range and effect data. Yet they scorned any calculation that tended to contradict their basic doctrine of attack. This doctrine, based in no small part on du Picq, concluded that the moral force was dominant in the success or failure in battle.[36] The élan and spirit of the French infantryman were counted as all-important in a clash of arms which would be decided by superior will and not by firepower, terrain or even maneuver.[37]

Taken literally, the French Army's unrestrained subscription to du Picq's theories would have resulted in a smaller army -- yet one (presumably) superior in moral power. It is therefore significant to note that, while the French announced that the moral force was predominant, they were quite consciously trying to match Germany step for step in mobilization potential (within the constraints of demographics), and materiel.[38]

Conclusions on the 19th Century

By the end of the 1800's, we can detect three distinct modes of thought about the use of calculations. The first mode was the classic 'overhead' calculations used by Napoleon to feed and move his army. The second mode probably started with the basic Napoleonic school, and then progressed towards the conviction that quantification of the phenomenon of combat, as exemplified by the German General Staff and Jean de Bloch, was necessary. The third (French) mode of thought embraced the Napoleonic 'overhead' calculations as well, but then became somewhat schizophrenic. On the one hand, the French embraced the works of du Picq and the opinion of the ascendancy of the moral force over all else. At the same time, they seemed not to trust this omnipotent 'moral force' and engaged with a 'bean-counting' approach to a military buildup designed to match the German buildup step for step. Both sides essentially continued a 'bean counting' approach during World War I -- operational movement of logistics was so slow that an enemy concentration could be spotted and a 'counter-concentration' begun.[39] In essence, until the start of World War I--

> . . . there were few opportunities to see the effects of the many technological advances in battle, and so the period between 1865 and 1916 is a case study of the relationship between theory and practice. It was a time of extravagant speculation. . .[40]

1918-1940

By the end of World War I, many scientists and mathematicians began to agree with de Bloch. They suspected that certain phenomena of battle may be subject to pure mathematical representation. In particular, the British mathematician Frederick Lanchester produced a series of equations, based on trench warfare, that purported to establish a quantitative relationship between the quality of units, their size, and the rates at which they suffered attrition when confronted by each other.[41] What we now call Operations Research (OR), or Operations Analysis (OA), registered marked progress between wars and " . . . soon went beyond simple questions pertaining to individual weapons."[42] In 1935, the sudden appearance of a technologically superior German Luftwaffe forced

Great Britain to establish the 'Tizard Committee'--a group of distinguished scientists and mathematicians who were to ". . . consider how far recent advances in scientific and technical knowledge can be used to strengthen the methods of defence against hostile aircraft."[43]

Left to its own devices between the wars, the U.S. Army gradually refined a five-part commander's estimate process adopted from the French Army. In the second part of the process, entitled 'calculation,' the staff conducted estimation and calculation of the constant factors of the situation (Relative Combat Power, Time and Space, Terrain, etc.) in combination with all appropriate methods of tactical action to deduce overall effects (preventing, hindering, favoring) on the action of friendly and enemy units.[44] The calculations used in this manual estimate process could not, of course, be either complex or lengthy. They were, in fact, quite similar to the rudimentary calculations that had been in use since the early 1800's -- and almost identical to the methods used today.

W.W.II - The Flowering of Operations Research

The first years of World War II saw great national concern arise about two areas of the war effort that were not going particularly well -- convoy losses to German submarines, and the poor results and high losses of daylight precision bombing. The relatively new science of OR helped commanders in both of these areas during the war. British mathematicians examined the effectiveness of different anti-submarine tactics, created a variety of mathematical models of operations such as search and attack patterns, and were subsequently able to recommend tactics that increased combat effectiveness by a factor of two.[45] However, the application of OR to convoy protection was initially misled by assuming that the best measurement of success was the number of German submarines sunk. Eventually, after months of frustration, the OR scientists determined that the number of convoys that completed the journey was the true measurement of success.

Through the use of OR techniques, the U.S. 8th Air Force increased its aggregate bombing accuracy by 60 percent before the end of the war. However, because of the difficulty in damage assessment, the success of the bombing campaign remained couched in terms of input (number of bombs dropped, sorties flown, etc.),[46] while German industry actually increased its output of war materiel.[47] Despite these problems, by the end of W.W.II, Navy and Army Air Force ". . . tactics ceased to be the sole product of military men operating by experience and rules of thumb."[48]

There were several probable reasons why this was so. First, Air Force bombing and Navy convoy battles were normally discrete and repetitive events with individual actors seldom numbering over 500. Feedback was usually available in the form of some sort of post-mission damage assessment. Data could be collected and sufficient time existed between events to analyze data. Second, the dismal record of convoy escort and daylight bombing early in the war applied very powerful pressure on both services to explore non-traditional solutions.[49] The pressure became so great that the Navy and Air Force conducted long-duration, large-scale OR experiments to find the best tactical solutions.[50] The new solutions were shocking. The Army Air Force had to retreat considerably from pre-war air power theories on unescorted daylight bombing,[51] and the Navy had to rely on the Air Force to help control sea lanes through the North Atlantic.[52] Given the inter-service competition of the 1930's, neither solution would have been conceivable without the urgency of wartime needs. As the direct result of wartime successes, the OR techniques of mathematically modeling combat phenomena to optimize naval and air battle tactics emerged from W.W.II with a ". . . considerable body of opinion strongly favoring its continuation in some form or another."[53]

However, this realization did not hold true for the Army, which largely ignored the OR tool to improve battle efficiency throughout the war[54] and continued to use classical Napoleonic calculations to determine time and space relationships, and rough force ratio determinations. The exception was the use of new methods to calculate logistics operations at the theater levels. Starting eighteen months before the Normandy invasion, logistics planners for Operation Overlord (including British OR specialists) succeeded in constructing a huge theoretical logistics model consisting of thousands of components with the aim of achieving ". . . a comprehensive view of all the factors that would effect the rate of flow" in order to allow them to select the proper beaches to assault.[55] Although the Normandy landings of June 1944 were a success, the logistics quickly became fouled, owing to several factors. First, the Allies occupied a shallow beachhead for a month, which resulted in tons of frustrated cargo remaining on the beaches. Second, this constipated logistical start was followed by a rapid pursuit that was not part of the pre-invasion plan, and which precluded the establishment of a coherent system of log bases and depots.[56] One may conclude that friction of war rapidly outmoded ". . . rigid mathematical modeling that failed to allow for human error."[57]

Overall, with materiel superiority assured, land combat in World War II progressed steadily for the American Army, with the result that there was no great political pressure to explore new ways of doing business. The same general effect was noted in Germany:

> No doubt the almost unbroken German military successes of the first war years confirmed the highly competent military staffs in the view that they had no need to seek help from outside scientists, however brilliant. When the tide of war swept against Germany it was too late.[58]

The Soviet Example - W.W.II

Other Armies of the World War II were not so lucky, and Russia's early defeats and subsequent experience with quantitative decision aids is by no means unique. In the pre-war years, Soviet military thinkers such as M.V. Frunze, V.K. Triandafillov, A.A. Svechin and M.N. Tukhachevsky produced Soviet concepts for modern mechanized warfare. Theirs were imaginative, creative minds, searching for optimum doctrinal solutions in an age marked by rapid technological change. We now recognize that many Soviet perceptions of war in the 1930's differed little from those described in Soviet Military literature of the late 1970's and early 80's.[59]

In 1937 Stalin's purges of the military began, ". . . resulting in the loss of leaders who were experienced in conducting modern battle."[60] By the late 1930's the works of the Soviet theoreticians had been abandoned, destroyed or suppressed. Based on Soviet experience in the Spanish Civil War, the Soviet High Command became convinced that mechanized corps were not effective; they were therefore abolished.[61] These and other miscalculations caused profound damage to the fabric of the Soviet Army that would become apparent only in 1941. Even then, only looming disaster would drive the High Command to action.[62]

The Soviet General Staff took a direction early in the war that was not surprising. From a social and political point of view, the approved framework of military thought was scientifically oriented since the Marxist method

> . . . is a method of thinking scientifically . . . . There exists a whole number of sciences upon which military affairs rest. Included among them essentially are all the sciences from geography to psychology."[63]

Thus, the primary frameworks for approaching military affairs in the Soviet Union would include quantitative techniques as a minimum, and since ". . . war itself is not a science -- it is a practical art, a skill,"[64] some mechanism to join the quantitative aspects with the human effort.

The ability of OR to quantify ground battles was fundamentally limited by both the scope of phenomenon and the accuracy of the data collection. Ground battles were less restricted to the pure performance of machines, as naval and air battles undoubtedly were. Ground battles could potentially continue for weeks, and unfold over thousands of kilometers of vastly differing geography. Accurately modeling land warfare in this era was therefore understandably difficult. The Soviet Army's solution to this problem was to create a special staff section in each Front and Army, whose job was to observe and record battlefield activity, in order to analyze it and make recommendations toward the improvement of operations.[65]

In a Directive of the General Staff, the Analytical Staffs of Fronts and Armies were instructed to record the following data elements concerning each combat action or 'new combat procedure':

1. The situation in which the action occurred.
2. The time and place of the action.
3. Enemy forces and nature of enemy opposition.
4. Detailed description of the action or the new combat method.
5. Detailed descriptions of the results, with indications of demonstrated advantages and disadvantages.
6. Conclusions and recommendations.[66]

The subsequent shape of Soviet thinking about numbers and war will be covered later in this chapter. Suffice it to say that the data gathered and analyzed by these Front and Army OR staffs during the 'Great Patriotic War' had a tremendous impact on subsequent Soviet military affairs.

Conclusions from W.W.II

For the most part, only those forces that suffered dramatic defeat and then survived were inclined to change long-standing patterns of behavior and begin using new decision aids such as Operations Research. The Soviets exhibited a pattern of reaction similar to Allied command over the convoy battles and precision daylight bombing. When the harsh reality of failure in combat finally forced the military leadership of America, Britain, and the Soviet Union into paradigm-breaking action, the approach in each case was similar:

- Discard existing 'rules of thumb'
- Create and conduct a series of combat experiments
- Analyze data
- Optimize the tactics

In each case, the use of mathematical models would assist the combat decision maker -- over time -- to overcome the tactical problem. Theater logistics was an exception, and the per capita-style 'overhead' calculations used since the days of Napoleon were transformed into the new language of OR to model the complexity of re supplying over the beach.

1946-1961: The De-Flowering of OR

The next 1_ years found the United States largely at peace. yet constrained by the wartime economy of the Cold War. Without the intense pressure of wartime tactical problems. the application of OR turned towards the general pursuit of military science. the procurement of new materiel and force design and, increasingly, the use of nuclear weapons. The first decade after World War II

> . . . saw the confluence of mutually reinforcing trends coming from opposite directions. On the one hand, advancing technology brought computers capable of processing huge amounts of data which, however, had to be presented in mathematical form. On the other hand, developments in the science of war led to the application of mathematically-based methods . . . to the conduct of operations.[67]

By 1948, the Air Force routinely referred analysis on matters of national security policy and long-range planning, to the RAND Corporation.[68] One of the best examples of the use of systems analysis in the post-war period was a 1951 combined study of the selection of overseas Strategic Air Command (SAC) Bases and the procurement of new bombers. The analysts pointed out that the

> . . . choice of bases was crucial in determining the make-up, destructive power and cost of the entire strategic force. The cost of acquiring, building, maintaining, and operating bases alone was not sufficient criterion to employ in selecting bases. The geography of bases affected the costs of extending the range of planes which could not reach targets without refueling. It affected the routes bombers had to fly through enemy territory and, thus, their potential losses enroute. The vulnerability to attack and, thus, the resources necessary to keep the bases operational and the costs of disrupted service, varied with location.[69]

As a general rule, the Air Force depended heavily on this type of analysis throughout the period to help determine how to fight a type of conflict never fought before -- nuclear war. The balance of national security in the thermonuclear age was far too precarious to permit a hit-and-miss acquisition strategy similar to that used by the U.S. in World War II.[70] The rising costs of development conspired with the destructive power of the bomb to turn the standard military 'trial and error' process of materiel and force design into something more similar to 'trial and catastrophe.'[71]

In 1948, the Army established the Operations Research Office (ORO) under a contract with Johns Hopkins University. The relationship between the Army and ORO was strained from the beginning, and this strain was probably best demonstrated by the controversy surrounding the M-14 rifle. The Army wanted a very lightweight service rifle that could fire .30 caliber ammunition accurately at 1,000 yards. First, small arms designers told the Army that they simply could not produce a weapon that met the desired characteristics of weight, reliability and accuracy. Second, the ORO had shown that small arms were rarely fired at 1,000 yards. The Army was unwilling to believe either, and remained reluctant to change its specifications.[72] This illustrates the basic problem of military judgment first having both to trust and to need Operations Research before actually being able to use it. Throughout this period, the nature of the OR game was beginning to change, even as the Army was debating the results of its first studies -- away from science and towards speculation.

Shortly after World War II, the wartime science of Operations Research, which had previously been concerned with quantitatively optimizing the combat performance of <u>existing</u> tactics, equipment and force design began to change.[73] In its place emerged the techniques of Systems Analysis, which dealt with the optimization and procurement of future weapon systems. Not all OR scientists welcomed this change, because it marked a departure from the purely quantitative into the qualitative and, increasingly, into the speculative:

> One suspects that the fear of losing professional respect was not the only restraint keeping the OR men from moving vigorously into Systems Analysis. As one perceptive analyst expressed it, when the scientist leaves the realm where knowledge is king, he must compete with other skills and adopt another life style . . . Where the scientist's allegiance is to truth, the decision maker's allegiance is to the organization he serves. The decision maker says, "What must we do now?" not "What can we learn here?" If the scientist expects to sit in the top councils and enjoy the pay and prestige of such positions, can he hope to retain the immunities and academic detachment normally associated with a scientific role?[74]

The problem was simply this--without an operation, there is no operations research. With full-scale maneuvers prohibitively costly or physically impossible in some instances, and banned by international treaty in others, realistic tactical experience grew thinner and more reliance had to be placed on extrapolations from ever more remote combat actions of the past.[75]

Moreover, the concentration of OR expertise on materiel acquisition did not meet with overwhelming success. This period, as well as those that followed, was marked by

> . . . increasing intrusion of secretariat-level authorities in questions that were once decided by operating commands. Such intrusions have occurred, and have subsequently been institutionalized, either because a

service refused to make choices, or because a service made such irrational choices that senior authorities concluded that they could no longer trust service judgments.[76]

1946-1961 Conclusions

At the beginning of this period OR techniques showed promise for qualitatively improving the ability of the U.S. Army to make decisions in combat. OR had already done this for the Navy, Air Force, theater-level logistics and the entire Soviet military system. Yet, the Army's command estimate process remained essentially the same. What happened?

First of all, Operations Research ran out of operations to research. Second, the relatively small group of OR experts were increasingly called upon to solve the problems of nuclear war at the strategic and national level. With a majority of OR effort at this level, the tactical thought process received little attention, which was probably fine with the Army- who (third) did not perceive a need to change it anyway. Fourth, the nature of Operations Research began to evolve towards systems analysis. This evolution represented a change from a quantitative and scientific approach to something often more akin to salesmanship of new materiel. As the services concentrated more effort on selling their systems or force structures to the budget-makers, and less on scientific analysis, the objectivity of their decisions became increasingly suspect. Finally, as the techniques and tools of OR became more complex, specialized, and <u>civilianized</u> they became less understandable and therefore less useful to the line commander.

1961-1972: The Tyranny of the Spread Sheet and Vietnam

The use of calculations to aid combat decision making during this period is perhaps best examined from two viewpoints: one from the strategic level, and the other from the tactical level. In many cases, the strategic failure of operations research overshadowed tactical successes of the science. When Robert S. McNamara took over at the Pentagon in early 1961, the time of the so-called systems analysts seemed to have arrived. Most of McNamara's crowd were economists, and hence had experience with computer modeling and data processing[77]:

> With computers acting as the stimulus, the theory of war was assimilated into that of microeconomics. Instead of striving to make the United States as strong as possible, McNamara and his team looked for ways of calculating how much was enough. Instead of evaluating military operations by their product -- that is, victory -- calculations were cast in input-output and cost effectiveness. Since intuition was to be replaced by calculation, and since the latter was to be carried out with the aid of computers, it was necessary that all the phenomena of war be reduced to quantitative form. Consequently, everything that could be quantified was, while everything that could not tended to be thrown onto the garbage heap. Among the things that were discarded in this way were precisely those factors that make war into what it is.[78]

Unfortunately, this approach had the disadvantage of alienating many senior Army officers who relied primarily on military judgment and intuition, and the feeling was somewhat mutual. There were those in the Secretary of Defense's office who continually searched for opportunities to ". . . sweep aside ultraconservative resistance within the Army."[78] McNamara himself was ". . . less concerned about each service's pet projects than he was about developing a worthwhile, cost effective defense program."[79] The effect of this general trend was to sour the Army officer corps -- particularly those from the combat arms -- on the usefulness of Operations Research:

> . . . many professional military men were irritated by the implication that computer calculations, operations research, and abstract theories would somehow have greater weight in the decision-making process than military judgment.[80]

This attitude continued beyond the mid 1970's --"There is a tendency in the Army to distrust operations research due to some rather unpleasant experiences with its use (or misuse) during the Robert S. McNamara -- Dr. Alain C. Enthoven regime."[81] As the nation became deeply committed in Vietnam, the combat arms of the United States Army finally came face to face with an insoluble tactical problem in the form of the Viet Cong (VC) and North Vietnamese Army (NVA). Much like convoy protection and daylight precision bombing problems of W.W.II, mathematical models would again be used by decision makers in the field.

Two of the most important decision makers in the Vietnam War -- McNamara and General William C. Westmoreland, had at one time or another, been associated with the Harvard Business School, appreciated mathematic decision-making tools, and surrounded themselves with men whose predilections were similar. Therefore, the favorite lens through which the American defense establishment chose to understand, plan, and wage the war in Vietnam consisted of statistics and OR.[83] In order to apply operations research successfully to a war-time problem, one must (eventually) determine measures of effectiveness that are directly linked to the overall objectives.[84] The first question asked a group of 173 Army general officers in a survey conducted after the Vietnam War was "Were U.S. objectives in Vietnam clear and understandable?". It is significant that over 70 percent of the senior leaders charged with fighting the war answered other than yes.[85] While Vietnam -- a war without fronts -- was difficult to understand without some reference to statistics, it remains doubtful that OR could succeed as a theater-level decision aid when 70 percent of the senior leadership could not clearly determine theater-level objectives.

Predictably, by 1964, the proclivity of McNamara to deal in statistics resulted in the Military Assistance Command-Vietnam (MACV) attempting to measure all battlefield phenomena either in terms of input (sorties, fire missions, etc.) or in output (body counts). By 1966, the various reports using combat statistics were drawn together under the overall "Measurement of Progress" (MOP) system.[86] The monthly MOP report for June of 1967 consisted of over 70 transparencies, and contained data on the following:

- Strength and strength trends of friendly and enemy forces
- Efforts of friendly forces in sorties

- Percentage of time that battalions spent on various types of missions (that month, 86 percent of all possible battalion time was spent on search and destroy missions)
- Enemy base areas neutralized
- Enemy losses
- Degree of government control of roads, villages, districts, etc.

The report concluded with the following summarized statistics:

- "Enemy base areas 37% neutralized, a decrease of 13 % from previous month."
- "Roads adequately secured 86%, an increase of 1% from previous month."
- "Waterways 12% secure, a decrease of 5% from previous month."
- "Population controlled by government 61%"
- "Attrition of enemy manpower was greater than his new input of manpower for the first time."[86]

In general ". . . the war and its total environment were so foreign to classic western experience, military and civilian, that one could not grasp it well at the time much less understand it. . .",[87] and the statistical approach was the primary method to come to grips with a problem that, by 1967, had become serious.[88] Much post-war criticism centered on the use of body counts as indicators of success:

> A high body count, it was alleged, became a career necessity for ambitious officers and led to falsification of reports, sapping the integrity of the officer corps in the process. More serious allegations concern the unnecessary civilian and. . . military casualties incurred by going after a high body count.[89]

The practice of body counts should have been questioned shortly after the introduction of American ground forces into Vietnam. Early interrogation reports revealed that the average North Vietnamese Regiment commonly estimated its casualties before an attack, stealthily dug the requisite number of camouflaged graves along their main attack routes and created companies whose job it was to drag NVA bodies back from the objective to these pre-dug graves.

Combat casualties may never have been a particular center of gravity for the U.S. to concentrate on in any event. Historians subsequently recognized other areas, such as the activities of the Viet Cong infrastructure, as being more critical to the NVA war effort than combat casualties.[90]

Concentration on the dubious indicator of body count statistics, however, caused most to miss the useful work done by Operations Research at the lower levels of MACV. In general, OR efforts at the divisional and corps level focused on two areas -- logistics and asset management, and enhancement of combat operations.[91]

Two of the most important facets of asset management which subsequently affected combat operations were numbers of both infantrymen and helicopters available on a daily basis. In the 9th Infantry Division and II Corps, application of Operations Research in these two areas alone resulted in a 350 percent increase of available infantrymen and a 30 percent increase in helicopter availability.[93]

Enhancement of Combat Operations took discrete phenomenon, such as casualties from booby traps, and applied OR techniques either to optimize or to reduce the effects of these weapons. OR reduced the impact of booby traps on the force by 20 percent.[94] In the case of balancing the right proportions of day and night combat, overall efficiency was increased by 200-300 percent.[95]

Conclusions for 1961- 1972

Institutionally, the U.S. Army was still in its infancy in the intelligent use of calculations as decision aids. As shown in the previous section, the Army had neither the pressing need nor the trust to tolerate OR analysis that produced an answer contrary to military judgment. The activities and demands of Secretary McNamara undoubtedly forced the Army towards using OR as a supplement to military judgment and more than merely a materiel acquisition tool -- and the Army undoubtedly resented it.

The lack of clear progress on a map led the MACV to start using numbers to indicate progress in the war. Staff officers formally wrapped all these statistics into a package called the Measurement of Progress System - specifically for McNamara's consumption.[96] The Army was trying to give McNamara what they thought he wanted, but it was obvious that the Army did not understand how to use these figures in the true OR mode, which caused McNamara's Systems Analysis Office to continually question MACV's numbers.[96] It is also doubtful if a theater-level analysis would have succeeded, given the lack of a clearly understood mission.

Put bluntly, the Army was in dire straits and, like other forces in other eras, necessity impelled the Army to examine non-traditional approaches to tactical problems normally handled by military judgment. A materiel developer, Major General Julian J. Ewell, and Colonel Ira Hunt from the Secretary of Defense's Office -- two officers who undoubtedly understood formally how to use OR -- would combine to provide the most meaningful OR efforts of the war. They took discrete battlefield events -- limited in duration and scope -- applied simple operations research techniques and quantitatively improved combat operations in their Division's area of operations. The efforts of Hunt and Ewell stand in contrast to the overall poor marks that history consistently gives to the Army's OR effort in Vietnam.

1973 - Today

Late in 1973, the Army shook itself out of the Vietnam stupor to study the results of the 1973 Arab-Israeli War. Two years later, the Army's awakening would result in the publication of a new version of FM 100-5 (Operations) and a collection of revised 'How to Fight' Field Manuals. The key elements of these manuals were the stark examination of U.S. and Soviet weapons' capabilities. In November 1974, the U.S. Army's Training and Doctrine Command (TRADOC) Chief of Staff, Major General Burnside E. Huffman outlined the basic approach to this doctrinal revision. Tactics had to be based on hard facts, and had to be taken out of the abstract. TRADOC had to examine the most recent military experience, and employ the best weapon data -- such as that being developed by the Army Materiel Systems Analysis Agency on hit probabilities of the newly captured Soviet weapons as a function of range. Concrete realities had to shape tactics.[98]

Weapons had become far more lethal than their World War II counterparts. The American medium tank of World War II needed 13 rounds to obtain a 50-50 probability of a hit at 1,500 meters: the M-60 tank of the 1960's needed one round. [99] Anti-tank guided missiles presented significant problems for Israeli tanks in the Sinai desert. The Israeli Air Force had to deal for the first time with an integrated air defense umbrella, and lost aircraft at an alarming rate. The new FM 100-5 addressed night vision systems, the irreducible effects of terrain, and attack helicopters -- all in terms of technical performance. In short, the 1976 version of FM 100-5 moved the Army closer to an OR approach to tactical decision making. Records of GEN Depuy's conferences reveal how the quantitative aspect of war affected doctrine and materiel issues:

> . . . it is a question of servicing targets . . . it is a very important part of our problem . . . the dynamics, the measurements, the numbers, the times, the vulnerability . . . . So in your calculation . . . here is what happens if we can reinforce with helicopters, and here is what happens if we cant; here's what happens with the XM-1 and here is what happens with the M-60; here's what

> happens at night and here's what happens at day -- with and without the thermal sight. [Throw these things] . . . into a Corps battle [simulation] and measure it.[100]

However, the 1976 version of FM 100-5 concentrated uniquely on the Soviet threat in Europe, and proposed movement schemes that many thought impossible. It focused on a European high-intensity battle that had much in common with the '73 War. For these reasons, among others, TRADOC began work on a completely revised FM 100-5 in 1977.

Meanwhile, without operations to analyze, OR specialists returned to the role of systems analysis and materiel development. The pattern in which ORSA-trained combat developers acted as 'systems salesmen' is best described by former commander of TRADOC, General William Depuy:

> When the development community launches a new effort or proposal, it knows that it must show a decisive improvement over the older model with the same function . . . A common argument is that the old model has reached its technological limits and it is now necessary to start from scratch. The amusing fact is, that just as soon as the new model is securely lodged in the program and budget, the development community discovers marvelous ways of improving the older system. You can bet your farm that the product-improved older system was not given a fair comparative evaluation during the decision-making process . . . .The materiel command agencies are in the unique position of being the prosecutor, judge, and jury against any threatening competitor.[101]

The 'system salesman' approach to OR continues to cast doubt on the objectivity of OR specialists to this day.

Throughout this period, national military strategy still rested heavily on delivery of nuclear weapons. The focus of the Army was on the defense of Western Europe, and the Army's role was to occupy a forward line of defense in Western Germany. Little large-scale maneuver was involved, since political constraints within theater required NATO to occupy forward positions. This particular focus has remained fixed for nearly forty years. Large unit movement, a skill so critical in W.W.II, now largely vanished from familiar use:

> U.S. Army commanders and staffs are ill prepared to practice operational maneuver doctrine because they neither learned how to do it while attending Army schools nor practice moving large units over great distances during exercises. For numerous reasons . . . the U.S. Army does not move large forces, such as a complete heavy corps, in peacetime exercises.[102]

Consequently, the Army's ability to use calculations in the tactical decision making process probably regressed. That process has not changed appreciably from World War II days which, as already discussed, was close to the same techniques used in the early 1800's.

In 1987 the Command and Staff College succeeded in incorporating into FM 101-10-1, "Staff Officer's Field Manual, Organizational, Technical, and Logistical Planning Factors," a majority of the different calculations used by the Army's different branches. The preface to this ma- -al explains that its purpose is for use by ". . . staff officers at all levels as a guide for obtaining planning data in support of combat operations."[103] Although the Army should be applauded for finally packaging a majority of the support calculations together with the logistics consumption data base, the manual represents very little improvement over the per-capita logistics calculations used by Napoleon 180 years ago. Other sources of Army data on calculations include Student Text 100-9, "The Command Estimate Process," which used a number of quantitative tools and tables derived from the 'Jiffy' manual war game[104], Student Text 100-3: "Battle Book," and Student Text 101-6: "G1/G4 Battle Book."

Meanwhile, the improvement of digital processing technology allowed more processing power and memory to be packaged into a smaller container. By the mid-1980's, the new science of artificial intelligence enabled specialists to join complex sets of heuristics with large data bases through the use of an 'expert system' installed on a small computer.[105] By the end of the 1980's, it was economically feasible to replace all of the staff's tedious 'stubby-pencil drill' with an expert system run on a laptop computer.

The Soviet Army

As noted earlier, the combination of powerful social and political factors and the specter of near defeat at the hands of the Germans drove the old Soviet Army to take a quantitative approach to combat decision making. By the mid-1970's, this approach had matured from simple tactical experimentation: "prediction is more and more based on scientific cognition methods, including quantitative ones, based on a study and a logical and mathematical description of the regularities of combat methods."[106] The study of the physical interrelationships of combat phenomena, and their subsequent codification in the form of 'norms' could be said to drive Soviet doctrine:

> Essentially norms are established in one of three ways: by analytical calculations, by production experience, and by statistical methods. In contrast with the western belief that analysis supplements experience, the Soviets consider that their analytical method is the most progressive and scientific; experience and statistical norms are secondary . . . . Establishing a norm is generally a two-step practice that involves, first, a calculation and, second, a trial of the calculated figure in order to confirm the norm . . . . Norms are listed under four headings: financial, supply, exploitation, and expenditure. The first three are essentially logistical while the last is both logistical and operational.[107]

The primary focus of Soviet norms was the need to accelerate the planning and decision-making process.[108] The Soviets saw the improvement of calculations as an important part of increasing the flexibility of operations -- that is, the rapid capability to plan for 'branches' or variants to the original plan. Additionally, the Soviets intended to ". . . speed up the processing of incoming data and make calculations more quickly by using computer technology, various tables, nomograms, slide rules, and other special calculation rules."[109] The Soviet system was integrated vertically; every commander knew the process and data used at levels above and below in the hierarchy, and horizontally throughout the combat and support arms. The Soviet textbook Tactical Computations was used to teach military norms to young officers, and it reveals a decided emphasis on movement and fire support computations.

Much like the German example of the von Schlieffen Plan, the Soviets felt a need to quantify a majority of battlefield phenomena. Like the von Schlieffen Plan, such an approach raises several valid issues. One point at issue is "How Much Calculation is Enough?" Second, we assume that to be of any use, the numbers that feed any system of calculations must be accurate. The problem of gathering <u>accurate</u> information in wartime is an extreme one:

> War consists of two independent wills confronting each other . . . though each of the contending opponents is to some extent bound by the nature of the means at his disposal and the environment in which he operates, neither those means nor that environment is ever so constrictive as to preclude considerable freedom of action. With each side free and, presumably, willing to double-cross the other to the utmost of his ability, the progress of the struggle between them is largely unforseeable. Consequently, the attainment of certainty is, a priori, impossible.[110]

The next problem is gathering <u>enough</u> accurate information:

> Everything else being equal, a larger and more complex task will demand more information to carry it out. Conversely, when information is insufficient (or when it is not available on time, or when it is superabundant, or when it is wrong . . .), a fall in the level of performance will automatically ensue.[111]

Last, there is the persistent evidence that the unpredictable actions of small units (both friendly and enemy) has incalculable effect on the outcome of the larger battle -- the basis of Clausewitzian friction. The Soviets themselves admitted that

> . . . mathematics cannot substitute for an entire complex of social, economic, and ideological substantiation essential for making . . . decisions. The adoption of mathematical methods not only does not negate the necessity of a qualitative analysis of phenomena but, on the contrary, is based on such an analysis.[112]

1972 - Present : Conclusions

Throughout this era, the impact of technology continued to grow, producing a greater variety of devices, weapons, and specialties for the staff and commander to deal with. The 1976 version of FM 100-5 embodied an effort to understand the effect of this accelerating technology through a quantitative approach to war. Later versions of FM 100-5, however, reverse this particular trend. By the end of the 1980's, the large-scale integration of digital computer technology into many weapons system technologies brought increased range, accuracy and lethality to a battlefield already cluttered with systems too complex to understand viscerally. Throughout this period, the command estimate process of the Army remained a manual drill quite similar in process to the pre-World War II version, although considerable assistance was available in the form of portable computers and expert systems. Operations Research, in the speculative form of systems analysis, continued to be employed in the materiel-development process.

A survey of current issues of Military Review for this period reveals few examples of numerical constructs as tactical decision aids, and few references to results of TRADOC battlefield modeling to support or even illustrate a tactical thesis. Paradoxically, while we live in a scientific age of complex mathematic methods, computers and Operations Research, the essays one reads in the Army's tactical journals are often nothing more than a string of opinions without much quantitative substantiation.

The Soviet system of mathematical models, or norms, stands in contrast. If a battlefield event is critical to the Soviet concept of war fighting, it is probably expressed in a mathematical construct. While the Soviet system obviously entails risk due to the unavoidable effects of human friction, it is far less likely to miss important emerging trends in weapons technology, or to overlook critical parts of the battlefield operating systems.

Much like the 1800's, the pace of technology threatens to outstrip the capacity of an antiquated command estimate process.

Conclusions on the Historical Perspective

While calculations, in one form or another, have been used from antiquity to aid military decision making, their use has been neither uniform nor universally profitable.

Napoleon used per-capita calculations to estimate gross logistics needs, and a manual time and distance calculation to mass troops at the decisive point. This practice was feasible for one or two men; its utility was unquestionable when battle was simple, and victory decided by valor and the bayonet. Napoleonic-style calculations have served every army since, and our own movement and logistics calculations are not substantially different. This traditional approach helps to maintain and move an army, but does little to help predict the winner of the battle. For the most part, the

Napoleonic tradition has enjoyed success -- primarily because it avoids trying to predict battle outcomes. Essentially, it consists of housekeeping or overhead calculations designed to manage assets between battles, and it leaves issues such as battle outcome up to military judgment. As powerful new weapons and machines of war flooded the post-Napoleonic battlefield, two trends began to emerge.

The French declared that the moral force of the infantry was the decisive element in war -- more important even than firepower or maneuver. While recognizing the utility of Napoleonic 'overhead' calculations, this school displayed schizophrenic tendencies and tried to match its enemy one for one. It could not predict the outcome of the battle, except with the remark that 'the strongest moral force will win.' Praxis was stronger than physics. This school is marked by the predominance of military judgment, experience, and the 'cult of the commander' over an analytical approach. While there is undoubtedly some truth in this approach, it cannot be used as a predictor of battle outcome because of the difficulty in comparing opposing moral forces. For the purposes of this thesis, this will be referred to as the 'Moral Force' school.

Count von Schlieffen quantified the battlefield to the point where he could predict victory in 'exactly 42 days.' Beginning with the Napoleonic 'overhead' calculations, and subsequent mathematical constructs of battle, such as the Kriegsspiel Apparatus, this school came to represent a line of reasoning that implied everything was quantifiable. After World War II, the Soviet Union developed an approach to war that used a unique mathematical framework of norms to both understand battlefield phenomena and provide decision aids throughout the Soviet military hierarchy. However, because the mathematical constructs of a complex battlefield must always leave critical elements out (the effects of human friction are quite resistant to accurate prediction), this school can never guarantee the prediction of battle outcome. For the purposes of this thesis, this will be referred to as the 'Quantification' School.

The historical perspective revealed several important secondary trends. In wartime, if a particular branch or mission sustains substantial losses, the organization is likely to shift from the Moral Force School into the Quantification School through the use of OR, or an OR-like activity. In fact, the urge to quantify can become so strong that experiments, complete with lives at stake, are conducted in combat to quantify those phenomena which conventional military judgment and experience fails to predict (such as convoy protection, precision daylight bombing, and guerrilla warfare).

One also notes an enduring peacetime attitude among Western military professionals to rely on military judgment and reject quantification, especially in an era where hard science is replaced by the 'salesmanship' of systems analysis. This attitude was perhaps best illustrated by the dichotomy that arose between the U.S. military of the early 1960's and the Defense Department under Robert McNamara.

The two opposing schools of decision making -- Moral Force versus Quantification -- are occasionally forced to join during war, especially under dire circumstances, and under the scientific examination of Operations Research. Powerful institutional forces then tend to split them apart again during the subsequent peace. Both schools strive towards the same goal -- the reduction of uncertainty on the battlefield and the efficient match between ends and means. Both schools recognize the need for some type of 'overhead' calculations in order to move and sustain a force. Both schools of thought have failed when misapplied, and both have succeeded when used in the appropriate context. The issue to be addressed in this thesis is the utility of calculations -- the school of quantification -- and its recognition as a useful tool for the tactical decision maker.

Impact on the Research Methods

This thesis is aimed at determining the utility of calculations as tactical decision aids. The two schools of thought illustrated by this chapter impact on this thesis in at least three ways:

1. Both schools support the use of Napoleonic-style 'overhead' calculations for movement and logistics functions.

2. Literature from the Moral Force school of thought rejects notions of complex force ratio calculations. Conversely, literature from the school of Quantification contains many methods of force ratio calculations, yet anecdotal evidence can provide many cases of small unit actions that violate the constructs provided by detailed calculation. This thesis will explore why this is so.

3. The tendency for the professional military to rely heavily on judgment, even in the face of contrary statistics, continues to this

day. This thesis forwards a more reasoned approach that explores the joining point between science and art.

CHAPTER THREE

RESEARCH METHODOLOGY

Introduction

The second chapter traced through a brief history of calculations as decision aids in war. Calculations in many different forms have always been used to assist the commander and staff, but their success has been less than consistent. Consequently, their acceptance by the professional military has always varied according to the 'fashion.' The second chapter also notes a natural tendency for the military decision maker to reject the use of calculations outright as an infringement on his professional judgment.

The third chapter examines several different approaches to research in order to select one that will adequately address the thesis question. This chapter will then develop the best research approach into a research methodology.

Selection of a Research Design

Every research design has inherent strengths and weaknesses.[112] A research method relying predominately on interviews, surveys and questionnaires might reveal the extent of professional biases toward one school or the other, but may not help resolve the issue of whether quantitative decision aids have utility at the tactical level. Obviously, various forms of quantitative models and Operations Research must be used within the research design, if only to demonstrate the technique. However, the research method should apply equal emphasis to both schools of thought. It therefore requires a technique that serves to adequately depict the battlefield effect of moral forces, as well as the quantitative.

One research design that can adequately illuminate both schools simultaneously is an analysis of a series of historical case studies. Since space is limited, the case study selection criteria should ensure that powerful moral forces are brought into inevitable conflict with equally powerful, quantifiable battlefield phenomena. Selection criteria for each case study should ensure that enough quantitative and human data exist for analysis. The subsequent analysis will then serve as a conceptual 'referee,' that will adjudge the relative strengths and weaknesses of each school within each case study.

Although this research design has inherent strengths, it also has weaknesses. One weakness is the difficulty of selecting cases for study which are known to be 'definitely typical.'[113] While every battle is decidedly atypical, there are common elements among most battles. In audition, within many battles there are commanders who simply are unfamiliar with what is possible and what is not. Chapter Four of this thesis will concentrate on isolating those common elements, and making qualitative observations on what 'is possible and what is not.' A second weakness is scope. Within the limitations of this paper, it is impossible to adequately treat every battlefield phenomenon. For this reason, the major battlefield phenomena will be discerned in Chapter Four--and case studies will be constructed to examine the relative strengths of each of the two schools of thought within the phenomenon. A third weakness is subjectivity. With possible thousands of adequate case studies available, the selection of a small number of representative samples naturally involves elements of subjectivity. As mentioned above, the general method will be to select well-documented battles where very powerful moral forces are brought into direct confrontation with equally powerful physical limitations. The challenge will then be to adjudicate the resulting meeting of the 'irresistible force against the immovable object.'

Methodology

The first step in the methodology is to delimit the specific battlefield functions that are subject to quantification. The U.S. Army uses several different frameworks to conceptualize battlefield phenomena. One is called the Battlefield Operating Systems; another covers the doctrine, training, organization, materiel, leadership and soldier quality of the force. The former Soviet Army used a framework that included the enemy, the relationship of opposing forces, the terrain and weather conditions, and 'how to fight.' Clearly, different armies conceptualize the broad phenomenon of warfare in different ways. The challenge in this step of the methodology is to identify phenomena common to most conceptual frameworks.

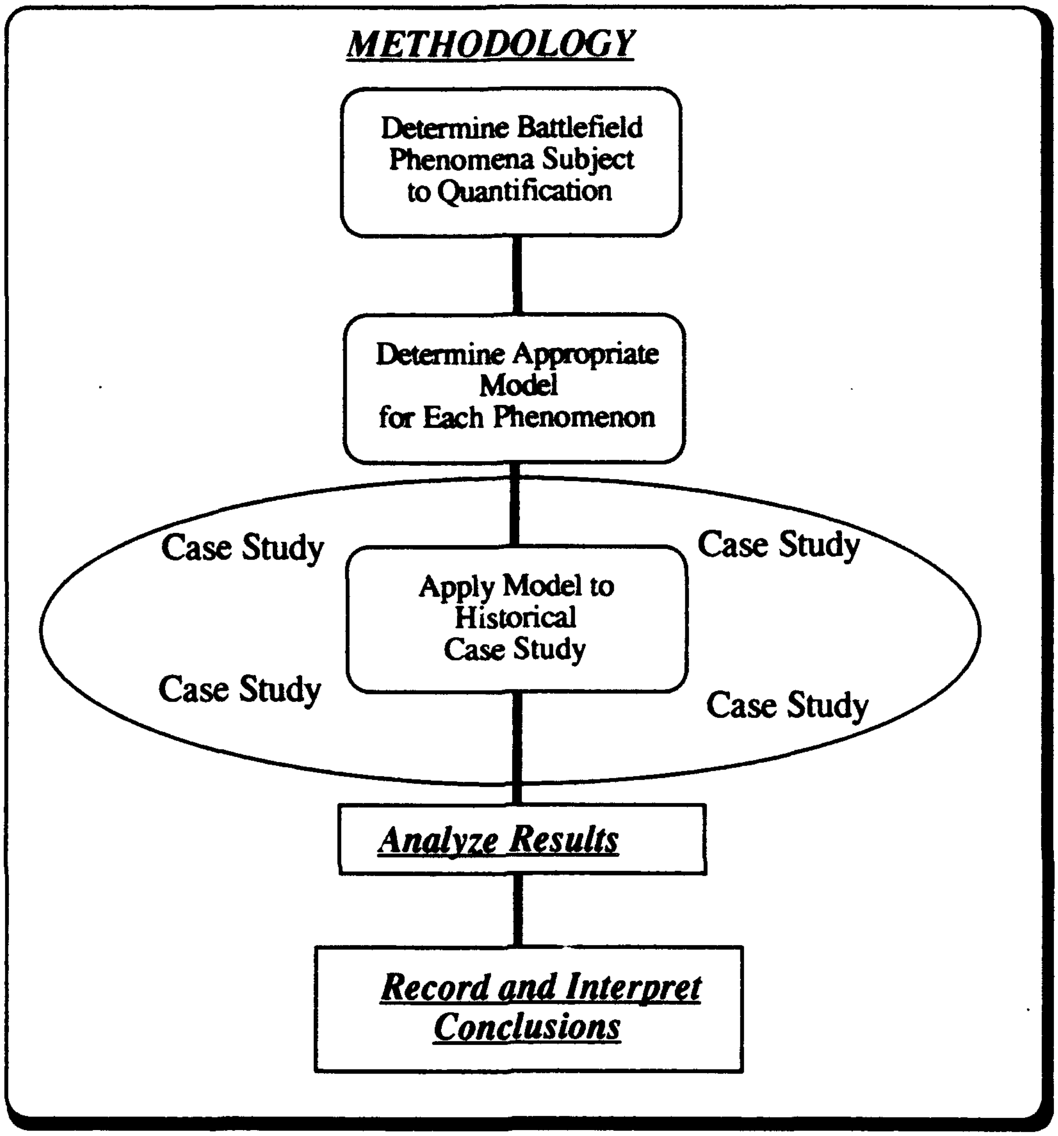

Figure 1. Research Methodology

The next step will be the determination of an appropriate quantitative method to aid the decision maker in the conceptualization of each battlefield function. Each quantitative method must be simple to apply, and should model the specific battlefield phenomenon to a degree of accuracy that qualitatively aids the decision maker.

The third step will be the application of these quantitative aids to analyze several brief historical case studies. Case studies will be selected to adequately illustrate the specific battlefield phenomenon under examination. The analysis of each case study will try to determine whether the use of a quantitative decision aid would have assisted the decision maker in that case study.

Finally, through the analysis of the case studies, this thesis will establish one of three conclusions:

1. That quantitative decision aids can consistently aid the commander and staff in reaching better decisions, and identify those battlefield phenomena most subject to quantification.

2. That quantitative decision aids have serious shortcomings as decision aids, and identify those battlefield phenomena least subject to quantification.

3. That quantitative decision aids can consistently aid the commander and staff in reaching better decisions about some battlefield phenomena, but have serious shortcomings when used to reach decisions about other phenomena.

Conclusions

The research method seeks to explore the boundary between the moral force and the quantitative schools of decision making to reach conclusions about the relative utility of quantitative decision aids at the tactical level. In order to do this, the research methodology must first define a common framework of battlefield phenomena. Each phenomenon may posses a set of existing quantitative decision aids--if so they will be documented in a series of appendices. Based on this framework of battlefield phenomena and quantitative decision aids, historical case studies will be selected that bring both schools of thought into conflict. An analysis of these case studies will enable us to reach conclusions about the relative strengths and weaknesses of each school of thought, and then directly address the thesis question.

CHAPTER FOUR

BATTLEFIELD FUNCTIONS AND APPROPRIATE MODELS

Introduction

This chapter seeks to delimit the specific battlefield phenomena that are subject to quantification and subsequent use as decision aids. The methodology in this chapter will first use a brief literature search to identify battlefield concepts acceptable to most contemporary frameworks of thought. Then, this chapter will isolate acceptable quantitative methods that effectively serve as decision aids for each phenomenon.

Battlefield Phenomena

Different armies conceptualize the battlefield in different ways, and even the same army may parse the battlefield up differently at different times. Complicating the matter is the fact that, in any analytical discussion of battlefield dynamics ". . . you get the illusion that all those parts are just there and are being named as they exist. But they can be named quite differently and organized quite differently depending on how the (analytical) knife moves."[114] Clearly, we need to progress beyond the mere choice of words and fashionable trends to get at the essence of battlefield dynamics:

> It is possible to argue about the exact nature of (battlefield) functions; one pundit will distinguish between striking, protecting, and moving, whereas

another will extend the list to include fixing or holding the enemy, intelligence gathering, communicating, supplying and so on. Whatever the list we care to select, the critical point is that they are rooted in the very nature of war and thus immune to technology and the kind of change it effects. Supplying . . . and communicating; gathering intelligence and securing against surprise attack; fixing the enemy, maneuvering, protecting and striking; each and every one of these were just as vital to a Neolithic horde as they are to a modern army.[115]

Armies have several undisputed elements in common that transcend both era and terminology. First, that destruction or violence (of all types) is the principle means to impose one's will in war. Second, that the violence generated by either belligerent is subject to a cognitive control of some sort. Third, that before large scale violence can be prosecuted, movements of men and war materiel must take place and, fourth, that the act of movement, the prosecution of violence, or even the maintenance of the capability to do either requires the consumption of logistics. Finally, one must recognize that man himself is at the core of all these activities. For starters, at least, these are the basic elements of war: movement, logistics, destruction, control, and man himself. The remainder of this chapter will examine three of these five areas--movement, logistics, and destruction--to identify acceptable decision aids for use in case study analysis.

Section One - Movement

> The Commander of an Army . . . need not understand anything about the make of a carriage, or the harness of a battery horse, but he must know how to calculate exactly the march of a column, under different circumstances, according to the time required.[116]
>
> - Clausewitz

The historical review in chapter two briefly described Napoleon's process for estimating time and distance relationships of units on the march. It also described the expansion of the German General Staff's Railway Department in the late 1800's to harness the mobilization and deployment power of the railroad. Through the last two centuries, decisions regarding movement have been consistently aided by, if not entirely dependent upon, quantitative techniques.

On the strategic level, movement takes place upon cargo aircraft, ship or railroad. Today, a strategic movement is so complicated that it is calculated entirely with a system of computers. At corps level and below, however, today's movement planning remains quite similar to its Napoleonic counterpart. Through the use of standard movement calculations found in Appendix A, one can easily visualize the relationships between time, distance, number of routes, and means of movement in a nomogram similar to Figure Two (below):

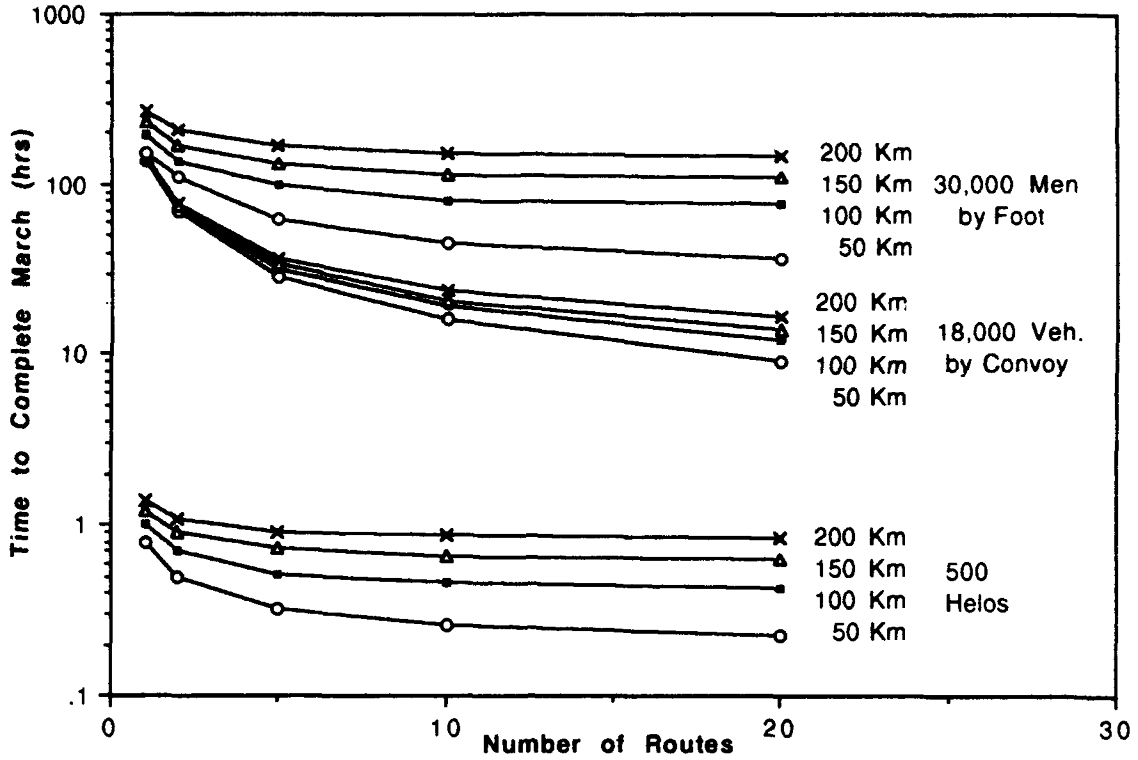

Figure 2. General Relationship Between Distance, Time, Number of Routes, and Means of Mobility

While Figure Two describes the general relationship between the different means of mobility available to today's U.S. Corps structure, specific quantitative decision aids are always used for movements of specific units over specific routes. Among these are march graphs showing distance, column length, pass time, and halts, etc.

While the effect of human friction is still found in unit movements, as a general rule, friction plays a less significant role than in combat. The U.S. Army FM 55-30 allows for friction by adding an Extra Time Allowance (EXTAL) for different sized march serials -- usually about 10-20 percent of the calculated pass time for the serial. During the stress of war, however, units have occasionally recorded EXTALs of up to 40 percent over their predicted marching times.[117]

The details of Figure Two (above) indicate that an adequate case study should illuminate the different results achieved by showing either asymmetrical means of mobility between opposing forces, an advantage in the number of usable routes of one force over the other, or a simple disparity of the distance required to move. The application of the quantitative decision aids in Appendix A to both sides of the case study will then demonstrate or refute their tactical utility.

Conclusions on the Movement Function

Throughout history, military professionals have used quantitative decision aids to make movement decisions. Today, these mathematical models are more refined, and largely automated. While the effect of human friction is still apparent in every battlefield activity, it has less of an impact on the movement function, especially if the primary means of movement is mechanized. The basic relationships between time, distance, routes and means of movement suggest a case study that illustrates a disparity in one of these four elements.

Section Two - Logistics

> When he first came to Africa, Rommel showed little interest in supply problems, but he came to realize that this question was absolutely fundamental.[118]
>
> - F.W. von Mellinthin

The Battle of '73 Easting,' one of the most violent battles of Desert Storm, lasted approximately 45 minutes. Yet, Coalition forces had waited up to six months to apply this 45 minute burst of combat power. This confirms the fact that actual fighting is only a small portion of war. Much must be tended to in order to get the machines of war prepared for their few instants of productive use. Even at the halt, a U.S. Division will consume hundreds of tons of supplies a day. Clearly, for a modern mechanized army, the problem of logistics is one that the tactician ignores at his own risk.

Chapter Two explored the use of per capita logistics calculations from the time of Napoleon to the present day. Napoleon's local requisitions and movement schedule during the Austerlitz campaign were coordinated by multiplying the number of men in any particular unit by the number of meals per day, and then by the number of days the unit would remain in a given area.[119] Whereas, in Napoleon's day, armies could feed from the countryside, today's mechanized units must have nearly all classes of supply delivered to them from a base of supply. Thus, a series of quantitative aids has evolved addressing not only logistics requirements, but the movement and handling of those logistics requirements as well.

Logistics requirements are normally estimated according to the type of consuming unit and its activity. For instance, in FM 101-10-1, staff officers must locate 12 different fuel usage rates for their unit in a table, and then multiply these numbers by 12 usage profiles found in another table. Summing the products, the staff officer generates fuel requirements for three different fuels in a particular geographic location. A similar method is used to estimate ammunition consumption, based on type of weapon, type of mission, and duration.[120] The details of these computations are explained in Appendix B of this thesis.

The transportation of supplies to the consuming unit is a separate problem, handled by several separate computations. Initially, one must calculate the number of trucks required to haul the tonnage required. Then, a calculation of the ability of the supply route to bear the required vehicle traffic must be made, including factors such as road surface type, terrain type, and effects of weather.[121] Again, the exact details of these calculations are found in Appendix B. Since this whole process requires road movement, movement calculations for convoys of supply vehicles must be included.

Hard evidence shows that war is often wasteful in terms of supplies used. Huge supply dumps have been built and then abandoned. Out of over 22 million 'jerry cans' used in the European theater during the latter half of 1944, ". . . more than half had been lost by August, with the result that this humble item limited the entire POL supply system."[122] The logistics effort required for Desert

Storm resulted in over 5,000 containers of 'frustrated cargo' that remained undelivered in the Saudi port of Ad Damman, due to a lack of adequate visibility and distribution means. While decisions concerning the logistical requirements of a mechanized army are almost completely dependent on quantitative tools, it appears that human friction still plays a significant role in increasing an already significant logistics burden.

The potential weaknesses of the supply function suggest that an adequate case study illustrating the value of quantitative decision aids would isolate a mission that went beyond its logistic means, either through a lack of supply, a lack of transportation, or an increased consumption rate.

Conclusions on the Logistics Function

Like movement, military professionals have commonly used quantitative decision aids to make logistics decisions. Again, these mathematical models have become more refined over the centuries. Recent history shows that the effect of human friction still makes a substantial impact on the logistics function, but planners are left with little choice other than to use quantitative aids due to the complexity of modern logistics. The basic relationships of logistic requirements, supply route selection, and movement suggest a case study that illustrates a shortcoming in one of these four elements.

Section Three - Destruction (Battle Outcome)

To a large degree, the outcome of any battle is determined by the interactions of men, machines and the environment. Of all calculations, accurate battle outcome prediction has remained the most elusive, most contentious issue throughout the history of quantitative decision aids. It is, in fact, the seminal difference between the two primary schools of thought -- a difference that centers primarily around the predictability of men in combat. Far from being widely agreed upon, quantitative aids for battle outcome estimates appear in many forms and many permutations within a form.

Quantifying Battle Outcomes

What makes battle outcome prediction such a contentious issue? To explore this question, one must isolate the primary variables that impact on battle outcome, and then examine each variable to determine if it can, in fact, be quantified. Any attempt at complete quantification of all battlefield processes has never been accomplished--and may never be. Even with a thorough understanding of OR techniques, and extensive computer support, "Combined arms operations at all levels . . . [are] too large and complex to study in toto by analytical methods."[123] This examination hopes to gain an appreciation why battle outcome calculations remain a topic of considerable debate.

Tactical Variables

An effort to isolate the prime variables of relative combat power can lead to a similar semantical jumble as the search for the primary battlefield functions. The framework for the prime variables chosen for this battlefield function is taken from current U.S. Army sources and background documents, which describe battle outcome as the result of the relative combat power of each belligerent. Then-Colonel Huba Wass de Czege, one of the primary authors of the 1982 version of FM 100-5, described relative combat power as a function of leadership, firepower, maneuver, and protection[124]:

TABLE 1

WASS DE CZEGE'S FORMULA FOR BATTLE OUTCOME

$$\textit{Battle Outcome} = L_f(F_f + M_f + P_f - D_e) - L_e(F_e + M_e + P_e - D_f)$$

Where -

L_f = friendly leadership effect	L_e = enemy leadership effect
F_f = friendly firepower effect	F_e = enemy firepower effect
M_f = friendly maneuver effect	M_e = enemy maneuver effect
P_f = friendly protection effect	P_e = enemy protection effect
D_e = enemy degrading of friendly firepower, maneuver and protection effects	D_f = friendly degrading of enemy firepower, maneuver and protection effects

Assuming this framework of battle outcome to be valid, this section will explore each major variable--firepower, maneuver, protection, and leadership--to determine if a basis exists for quantification.

Firepower

A firepower model measures victory or defeat by relative casualties suffered as a function of weapons lethality. This variable is relatively straightforward to model through deterministic methods, and usually serves as the conceptual basis for battle outcome prediction through force ratio calculations. We assume that deterministic models of firepower, such as Lanchester's set of equations, must represent the mean or average of what most consider to be an underlying stochastic phenomenon.[125] While stochastic models are relatively easy to construct, they are difficult to extract data from. Additionally, current academic thought also raises the notion that the ". . . combat environment can exhibit extremely erratic and even chaotic behavior under appropriate conditions."[126] Since Stochastic models require dozens of computer runs to generate a mean, and adequate chaos models of combat--which may incorporate the effects of maneuver--are still in development, the tactical decision maker is left with the simple deterministic method of force ratio calculations. Indeed, most armies today use only simple deterministic models of relative fire power in a tactical environment.

Maneuver

Maneuver theories, on the other hand, measure victory by relative disruption -- POWs, abandoned positions, and psychological impact. These particular phenomena are seen as difficult to duplicate mathematically. COL John Boyd, a well-known maneuver theorist, observed that:

> We do not have any models today that measure how you capture prisoners. They are all P_k or body count models or expected values which are nothing more than an accumulation of body count. So if they cannot measure that phenomenon that generates prisoners . . . (then) any model we have . . . is attrition warfare.[127]

Research by John McQuie of the U.S. Army's Concept Analysis Agency (CAA) indicated the magnitude of the modeling problem identified by Boyd:

> No matter how casualties are measured, battles have been given up for lost when casualties ranged from insignificant to overwhelming . . . .Just as for troop casualties, no dominant pattern emerges from a study of equipment losses . . . the principle condition associated with defeat appears to have been the use of maneuver by an enemy [64% of 80 cases studied].[128]

While realizing that the absolutely pure tactical method is rarely found, and that actual combat is always a mixture of maneuver and firepower, the statistical evidence suggests that maneuver has a greater impact on battle outcome than attrition. It seems intuitive, however, that some measure of firepower must always accompany maneuver:

> Consider, as von Neuman once did, the mongoose and the cobra: the mongoose wins by postures and movements before it strikes. The maneuvers are the battle, the strike behind the cobra's neck merely the consummation of what went before . . . Nevertheless, lethality will always be involved, for lethality is the substance of combat power.[129]

However, we lack an accepted model for the effects of maneuver, and we also note that effects of maneuver may well outweigh the effects of weapons. Additionally, we possess no model for combining the moral effects of maneuver with the physical effects of firepower.

Protection

COL Wass de Czege's combat power model describes two components of protection: protection from enemy action and the general maintenance of soldier's health.[130] Protection from enemy weapons can be simulated simply by reducing the mathematical effects of enemy weapons through reductions in a weapon's probabilities for detecting, hitting or killing its target. However, estimating the effects of protection from the psychological effects of maneuver are--much like the modeling of maneuver discussed above--difficult. Maintenance of soldiers' health is indeed a critical issue, since non-battle injuries have always caused a significant number of casualties in an army. While we can statistically predict non-battle injuries through historical data at division level and above,[131] we know that many of these injuries result from failures of leadership, training, standards, or individuals within smaller units, and can thus can vary widely from unit to unit.

Leadership

COL Wass de Czege called leadership "The most important, and often least understood, element of combat power . . . . Given the same parameters, good leaders can generate many more times more combat power than mediocre ones."[132] The primary combat applicators of OR in Vietnam, Lieutenant General Julian J. Ewell and Major General Ira A. Hunt, felt much the same way:

> A confusing element in the equation was and is that outstanding leadership . . . transcends or overrides the standard rules. One must always ask whether something works because it is executed by an artist, whether it is basically a good idea, whether it is too difficult for general use, and so on. To the artist with a deep knowledge of the war, a decision may appear simple and logical. To a less gifted person, the decision may seem illogical or based on intuition.[133]

While we intuitively feel the above true, the reverse must be true as well--that poor leadership creates exactly the opposite effect. Instead of victory, poor leadership leads to defeat, or disruption. Many (if not most) military operations hover dangerously on the brink of disruption without any enemy interference whatsoever:

> . . . disruption has historically not been necessarily the result of hostile threats or action alone . . . .disruption within a military force can be created by actions -- or inaction -- of

individuals or groups within that force, resulting from incompetence, oversight, misunderstanding, or even treachery.[34]

While COL Wass de Czege's framework identifies leadership as the prime variable of combat power, I could find no existing mathematical model of leadership to test what most professional military feel is true--thus, a prime variable is left unquantified.

Conclusions on Battle Outcome

Of the four prime variables listed by the U.S. Army in FM 100-5, only one is quantifiable at this point--If McQuie's analysis is correct, the best we can hope for in a deterministic approach to quantifying battle outcome is a disturbing 36 percent accuracy of the mean outcomes of casualties, and a 12 percent accuracy on the outcome of battles.[134] At the strategic level, there is convincing evidence that success or failure in war is related to attrition of manpower pools.[135] However, at the tactical level (as noted by McQuie) casualties do not correlate with battle outcome. An attrition model would predict neither prisoners nor the effects of positional advantage gained by maneuver. Perhaps the use of enlightened military judgment to divine battle outcome ". . . merely underline(s) the obvious point that the human mind can somehow grasp large problems by means which are difficult or impossible to duplicate on paper."[136] In an age of computer simulation, artificial intelligence, and expert systems, we are still closer to Napoleon in our approach to battle outcome prediction than many would admit. However, we accept that the effects of weapons represent the 'substance' of combat power. We also recognize that neither good leadership, nor adroit maneuver can enhance a weapon's effects beyond its theoretical maximum. As a baseline definition of combat power 'currency,' therefore, we must be able to articulate weapons effects in a clear and unambiguous manner. Appendix C to this thesis examines some common force ratio calculation tools, and evolves a different type of model for use in the case study.

Overall Conclusions

Two of the three battlefield functions isolated for examination--movement and logistics--reveal a long and successful history of quantitative decision aids, despite the ever-present human effects of error. Case studies for each of these areas should concentrate on the consequences of ignoring these tools. The third area, battle outcome, is commonly conceptualized through a variety of deterministic methods aimed at calculating force ratios. Force ratios are perhaps the simplest technique of determining relative firepower. The variable of firepower however, is only a small portion of the American concept of combat power. The other variables--leadership, protection, and maneuver--seem to make up the majority of combat power, and remain without adequate decision aids. The case study on battle outcome should concentrate on a battle where ignorance of one of these missing variables is critical to the decision maker.

CHAPTER FIVE

CASE STUDIES

Introduction

As mentioned in Chapter Three, the selected research design relies on an analysis of a series of historic case studies. A number of case studies were screened to select battles that brought moral forces into conflict with equally powerful, quantifiable battlefield phenomena. Some case studies were discarded because of a lack of quantitative data. Others, although ideal, were discarded because of a lack of adequate sources. As discussed earlier, this research design has inherent strengths, as well as weaknesses. One weakness is the difficulty of, and subjectivity involved with, selecting cases for study which are known to be 'definitely typical.' While every battle is decidedly atypical, there are common elements among most battles, and these were discussed in Chapter Four. The reader can perhaps claim that the battles selected as case studies are perhaps too atypical. Nonetheless, each case study illuminates important points, and raises issues central to the thesis question.

The second weakness is scope. Within the limitations of this paper, it is impossible to adequately treat every battlefield phenomenon. For this reason, the major battlefield phenomena will be discerned in Chapter Four--and case studies will be constructed to examine the relative strengths of each of the two schools of thought within three of the five battlefield phenomenon.

Despite these shortcomings, the case studies raise some critical points which were never imagined during the initial research phase of this thesis. As mentioned above, the general method will be to take these three case studies and, in the analysis, adjudicate the resulting meeting of the 'irresistible moral force against the immovable physical object'. This process has the added benefit of illuminating secondary insights which, until this point, have remained obscure.

Case Study One: Battlefield Movement

In Chapter Four, we examined the battlefield function of movement. The potential weaknesses of the movement function identified in that chapter suggest that an adequate case study illustrating the value of quantitative decision aids would isolate a battle in which a disparity of march times occurred due to different route structures, movement rates, or vehicle count. Chapter Four also briefly explored the continuing impact of human friction on the function of movement. Given this, and the fact that this thesis seeks to explore the boundary between the moral force and quantification schools of thought, we will use the ground campaign of Desert Storm - a case study that pits VII Corps moving on multiple cross-country routes against the bulk of the Iraqi Army trying desperately to escape on a small number of improved roads.

This case study will seek to determine the nature of the environment and route structure that confronted both opposing forces, and the rationale and techniques of movement used by both forces. It will then apply quantitative aids to this body of knowledge to determine the movement dynamics at work in this battle. The analysis of the relative movement of both forces will then be used to reach conclusions about the utility of quantitative decision aids.

The US Plan

The VII Corps was the sledgehammer designed to shatter the Republican Guard divisions in the Kuwati Theater of Operations (KTO). With the addition of the British 1st Armored Division, VII Corps represented the largest single armored force assembled by the army in 45 years --its zone of attack was some 50-100 kilometers wide and its logistics and reinforcing elements stretched 200 kilometers when on the move. VII Corps was to conduct a turning movement against the Iraqi Army in the KTO. The 1st Infantry Division (ID) would forge a breach in Iraq's line just west of the Wadi al Batin in order to pass the British 1st Armored Division (AD) through. Once the British were in Iraq, they were to turn immediately east and begin to roll up the flank of the Iraqi front lines. The 2nd Armored Cavalry Regiment (ACR), 1st and 3rd Armored Divisions, having gone around the end of Iraqi lines to the west. were to push farther north then turn east into the Republican Guard to complete the turning movement.[137] As the Corps turned east and reached the main Iraqi defenses, it would narrow its frontage and concentrate its combat power against whatever defense the Republican Guard could assemble. After destroying the Republican Guard, VII Corps was to continue to the east--cutting the highways running through the town of Basrah and trapping the bulk of the Iraqi Army.

VII Corps Organizational and Technical Data

VII Corps had some 59,000 U.S. vehicles, including over 1,000 tanks, 1,600 helicopters, and 100,000 soldiers. On the move, VII Corps would consume over 3,000,000 gallons of fuel a day.[138] With the addition of the 1st (UK) Armored Division, VII Corps had a strength of around 64,000 vehicles and 135,000 soldiers.[139]

The VII Corps Environment and Route Structure

In order to avoid the main Iraqi defenses and envelop the Republican Guard, VII Corps would have to move through the Iraqi desert - a region with few routes, landmarks or even satisfactory maps: the issue 1:50,000 maps looked like " . . . a manila folder with black grid lines on it - there is not enough relief [at] 1:50,000 [scale], so [the maps were] generally worthless."[140] Once in the desert, U.S. units realized that dead-reckoning navigation would not work with the distances involved and the lack of terrain features. The demand for electronic navigation aids such as LORAN[141] and GPS[142] skyrocketed early in the deployment. Around 4,500 GPS receivers -- enough for each maneuver company to have one -- were in the Gulf by the end of February, and another 5,000 were on order.[143]

With GPS ". . . American soldiers could navigate across hundreds of miles of Iraqi desert, where even the Iraqis found it impossible to go. Without them, [the Americans] would have been lost."[144]

The Iraqi Plan

Along the Saudi-Kuwaiti border, the Iraqis constructed the 'Saddam Line' of barbed wire, mines, fire trenches and infantry positions. Hussein's fixation on an attack from the south and up the Wadi Al Batin was reinforced by a U.S. Central Command (CENTCOM) deception plan, and he failed to extend his prepared defenses much beyond the Wadi. The Iraqi Army retained its mechanized and armored divisions in the operational depth, ready to respond to the Coalition attack. The elite Republican Guard remained positioned at the mouth of the Wadi Al Batin where it opens up onto a plain southwest of Basrah.[145] The entire Iraqi Army remained oriented to the south.

Iraqi Organizational and Technical Data

Iraq used a division organization with 11,000-13,000 men per full strength division,[146] and, according to one estimate ". . . up to 545,000 men, in twelve armored (or mechanized) and thirty other divisions, were in the Kuwaiti theater of operations."[147] There were 4,700 Iraqi tanks,[148] some 3,500 Iraqi artillery pieces (most towed with a prime mover) and rocket launchers,[149] and close to 5,000 APCs in theater.[150] Although the tables of organization and equipment (TOE) for the Iraqi Army were by no means standard, data does exist for the rough number of wheeled vehicles in battalion-sized units[151], and it is known that Iraq used a Soviet-style force design. Additionally, the density of light infantry divisions in the Iraqi Army caused Iraqi echelons above division to pool transportation assets into a group of over 20,000 vehicles that were used to move up to 12 infantry divisions at a time.[152] From this data, we can estimate that the Iraqi Army had approximately 77,000 TOE motorized vehicles in the KTO.

The Iraqi Environment and Route Structure

Despite the popular western image of Middle Eastern people as largely desert nomads, over 70 percent of the Iraqi population lived in urban areas.[153] While the nomadic tribes of Iraq habitually transited large parts of the desert on a seasonal basis, they represented only a small fraction of Iraq's conscripted Army. Additionally, the Iraqi population has an illiteracy rate of 45 percent. Thus, the average Iraqi soldier has only as much expertise at desert navigation as any other marginally literate urban-raised soldier. Since, in a featureless desert, navigation becomes a matter of life or death, the preferred method of travel of the Iraqi Army was on roads. This had two primary effects on the campaign; first, it made the Iraqis doubt that the coalition forces could attack through the trackless desert to the west;[154] and second, when the Iraqi Army began to move out of theater, it would do so on improved roads.

There are exactly five roads out of the KTO. One six-lane highway (Highway Eight), and a smaller four lane highway (Highway One), run west out of Basrah, along the south side of the vast Hawar Al Hammar swamp, before turning north west towards Baghdad. A second four-lane road runs due north from the Rumaliah oil fields over a long causeway built over the Al Hammar. The final two highways--old World War II Lend-Lease routes to the Soviet Union--run north from Basrah along either side of the Shatt Al Arab river. One of these is a four-lane, the other a two-lane up to Ash Shanin Duwa--a town 50 kilometers north of Basrah. In terms of military convoy traffic, these five highways equaled ten possible routes of march (routes with width greater than 2.8 meters). Forced over these ten routes by their fear of the desert, the Iraqis had to move at least 77,000 vehicles, and 20 foot-mobile infantry divisions from the KTO.

We should note that a larger number of secondary roads fed into these main highways. However, no road network can carry any more throughput than its most restrictive node--regardless of the number of feeder routes. For this reason, the initial calculations will consider Iraqi travel over:

- Ten military routes, which represent the total road capacity with all highways open.
- Five military routes, which represent only the causeway and the Shatt Al Arab highways, and
- Three military routes, which represent only the highways along the Shatt Al Arab.

Initial Calculations

From its tactical assembly areas just south of Tapline Road, VII Corps had between 200 and 300 kilometers of movement before it could cut the highways just south of Basrah with direct fire. We know that the 24th Infantry Division, when largely unopposed, " . . . raced 250 kilometers in 24 hours . . .,"[155] which results in a cross-country march speed of ten kilometers in the hour. This speed agrees with both the planning figure used in ST 100-9 and the modeling data used by TRADOC Analysis Command. We also know that the most constrictive part of the VII Corps route was at the obstacle belt. With the 1st Infantry Division clearing 28 gaps in the minefield, and 1st and 3rd Armored Divisions largely free of the obstacle belt, VII corps was probably traveling on over 60 routes. Using 60 routes, and with refueling stops enroute, and using a cross-country march speed of 10 kilometers in the hour (kih), the quickest the VII Corps could have completed this movement and closed into position south of Basrah was 47 hours.

Using a total of ten escape routes, the quickest the Iraqi Army's mechanized and motorized elements could have vacated the theater was 42 hours. With five routes, the quickest time was 75 hours. With only three routes, the quickest the Iraqi Army could have vacated its vehicles from the KTO was 119 hours. However, under any one of these three scenarios, most of its light infantry element (20 divisions) would have taken five more days, at a forced march pace, in order to reach Basrah.

None of these estimates factor in time lost due to combat or the effect of air interdiction on movement - they represent only the potential for movement of each army over the route structure available.

Initial Conclusions

Using the comparative movement potential of both Armies, we can begin to reach some initial conclusions about the value of quantitative decision aids in this battlefield function. From an examination of the mathematical relationship between distance, routes and numbers of vehicles, we note that a movement of any unit above brigade size is much more sensitive to the number of routes than to the march distance because of the effect of column pass times. Because of their cultural fear of desert movement, the Iraqi Army was essentially held hostage to the small number of improved roads out of the KTO. The Iraqi's slowest elements--its light infantry divisions--had the farthest to travel. The use of GPS means that the VII Corps can conceivably move on an unlimited number of routes, which results in a march time close to that of a single vehicle (little or no pass time). From an operational perspective, the Iraqis are fatally off balance. From August 1990 to January 1991, they have continued to re-inforce a theater with a severely limited route structure to the point where they lack the ability to move back out with all their assets.

However, if the escape routes available to them are not interdicted in some way, the initial calculations show that a substantial number of Iraqi vehicles can exit from the KTO in the 47 hours it takes for the VII Corps to cut off Basrah. Additionally, the major constriction in the route structure is the town of Basrah. If forced to use the three Shat Al Arab routes, much of the Iraqi army will be sitting idle, in and around Basrah itself, waiting for road space.

Execution

By 1000 hours on the 24th, the leading combat elements of the 1st ID were through the defensive line, and by 1800, two brigades stood abreast, guarding the breach.[156] After talking with his subordinate commanders, Lieutenant General Frederick M. Franks, Jr., the VII Corps Commander, ". . . decided to hold . . . the two armored divisions in place the night of their attack into Iraq to allow 1st Infantry Division . . . to complete the breach at daylight."[157] By the time this decision was made, ". . . the 2nd Armored Cavalry Regiment had moved nineteen miles (32 Km) into Iraq . . . "[158] After surging across the border at 1500 hours on the 24th, the lead elements of the ". . . 3rd Armored Division had advanced just 29 kilometers into Iraq on G-Day,[159] and at that depth, lead elements of 1st AD and 3rd AD halted at around 1800 hours that evening.[160] It was not ". . . until nearly noon on G-Plus-One [25 Feb.] that the last elements of the 3rd Armored Division crossed into Iraq."[161]

During the evening of the 24th, the 1st Infantry Division was ". . .busy cutting and marking a total of twenty-four lanes for the Corps to use the next day."[162] At 1200 hours on the 25th, ". . . the British 1st Armored Division began passing through, an operation that took until 0200 hours (on the 26th) to complete . . . the 1st and 3rd Armored Divisions had [already] cut their own breaching lanes through the border obstacles beyond the Iraqi's defensive positions.

where there was little opposition."[163] Despite the damage done to their communications, the Iraqis were now aware of the location of the VII Corps, and its general direction of attack.[164]

Earlier on the 25th, The CENTCOM Commander, General H. Norman Schwartzkopf had spoken with LTG Franks, urging him to shift into the pursuit phase of the attack. As a result, LTG Franks told his commanders -- "We are going to drive the Corps hard for the next 24 to 36 hours, day and night, to overcome all resistance and to prevent the enemy from withdrawing . . . we will have to crank up the heat."[165]

While some Iraqi units were preparing to stand and fight, other units--probably the majority of the Iraqi Army--was preparing to retreat. CENTCOM intelligence logs on the 25th indicated that the Hammurabi Division was preparing to pull back into Basrah, the Medinah Division had received orders to burn unneeded equipment, and the Tawakalna and 52nd Armored Divisions were moving into blocking positions.[166] Other intelligence sources picked up Iraqi communications traffic that indicated a major retreat was being ordered for the evening of the 25th -- a fact soon confirmed by Joint Surveillance, Targeting and Reconnaissance System (J-STARS) imagery which began arriving at Riyadh around 1640 hours.[167] By the time the retreat was ordered, the 101st Airborne Division (Air Assault) had occupied Area of Operations (AO) Eagle, cutting Highways One and Eight. Out of the ten convoy routes open to the Iraqis out of the KTO, five were now closed.

The 1st and 3rd Armored Divisions halted around Phase line Smash, 110 kilometers inside Iraq, around 2100 on the evening of the 25th.[168] On the morning of the 26th, the 1st and 3rd Armored Divisions conducted their first significant combat action at the Iraqi town of Al Busayya, some 130 kilometers inside Iraq.[169] At 0615 hours, VII the Corps began an artillery preparation on the entrenched Iraqi infantry division and the supply dump it was guarding.[170] The two heavy divisions rolled over the Iraqi 26th Infantry Division by noon on the 26th.[171] By mid-afternoon on the 26th, VII Corps had turned due east, following the 2nd ACR, which had located elements Tawalkana and Adnan Divisions of the Republican Guard. At this point, the commanding generals of the Republican Guard realized that the VII Corps was not turning to assault Kuwait City, but was instead heading directly at them-

> When the Iraqi generals realized their mistake, the mission of the Republican Guard became critically important. With so many Iraqi units fleeing to the north behind them, the Republican Guard divisions would have to block the VII Corps and prevent them from breaking through into northern Kuwait . . . and rolling up the retreating Iraqi Army.[172]

For six hours, the armored cavalry fought Iraqi units attempting either to flee or fight, ". . . beating off a series of attacks from three different tank brigades as the battle continued into the night."[173] At midnight on the 26th, the 1st and 3rd Armored Divisions began passing around the 2nd ACR to begin an attack on elements of the Tawalkana, 52nd Tank, and 12th Armored Divisions just west of the Iraqi-Kuwaiti border.[174]

By first light on the 27th, ". . . the entire 1st Armored Division was already moving forward, three brigades abreast. Their tanks were spaced thirty meters apart. The advancing division occupied a sector of desert fifteen miles wide."[175] To the south, the 3rd AD and the 1st ID narrowed their frontages in the Corps effort to concentrate as much combat power as possible on the Republican Guard divisions guarding Basrah.

VII Corps continued this attack throughout the 27th. By 1000 hours, the battle of Medinah Ridge was joined, as VII Corps crossed the Kuwaiti border-

> . . . in desperation, the Iraqis committed the 10th Tank Division . . . only to see it engulfed . . . . By mid afternoon, US and Iraqi formations were so intermingled further [close] air and attack helicopter support became impossible. Instead, they were sent deep, to take out the remaining tactical reserves and supporting artillery in the vicinity of the next day's objective . . . [176]

Pursuing the remnants of this force east, the VII Corps was halted at 0800 of the 28th by order of CENTCOM.

On the afternoon of the 27th, a series of battles began that effectively shut the causeway over the Hawr Al Hammar. One of the two concrete spans of the causeway was already partially damaged as part of the air campaign. The afternoon of the 27th found four AH-64 battalions of the XVIIIth Airborne Corps attacking vehicle convoys moving across the causeway. By the time the Iraqis cleared the wreckage, the 24th ID had arrived, and again blocked the flow of traffic with a battle two days after the cease-fire.

The final ground combat action that took place before the cease-fire was the seizure of the Safwan airfield by the 1st Infantry Division, which brought with it the added benefit of cutting the main north-south highway between Kuwait City and Basrah. However, as noted often in the press, this was the end of the 100-hour ground war. Even with only three routes out of Basrah, the Iraqis had enough time to move their vehicles (but not their infantry) out of the KTO.

J-STARS images clearly show that the three military routes running north out of Basrah along the Shatt Al Arab were never successfully interdicted. Two clear reasons exist for this lack of successful interdiction:

- Even when a bridge is dropped, the hydrology of the region often allows quick repairs to be made with only a bulldozer and a pile of sand. Feed footage from the Cable News Network (CNN) clearly shows this to be the case with regard to the causeway.

- On the 26th, the weather worsened significantly. Ceilings of unbroken clouds came down to only several hundred feet altitude. Blowing sand mixed with heavy oil smoke to further obscure precision-guided munitions. In these conditions, the interdiction effort was significantly reduced. By the time the skies cleared, the cease fire was in effect.

Heavy traffic continued to move out of the KTO on the three Shatt-Al-Arab routes for days after the cease fire.

End State

How many got away? It appears now that

> . . . about 4 1/2 of Saddam Hussein's eight Republican Guard Divisions--the Adnan, the Nebuchadnezzar, the Al Faw, the 8th Special Forces, and part of the Hammurabi--escaped the allied onslaught. This amounted to a force of well over 60,000 men.[177]

Additionally, postwar interviews suggest that ". . . at least half of the soldiers from Iraq's eight to ten armored and mechanized divisions escaped. Added to the Republican Guard figures quoted above, this would amount to around 110,000 Iraqi Soldiers.[178] The International Institute for Strategic Studies in London estimated that in October, 1991--eight months after the end of Desert Storm--Iraq had ". . . about 2,300 tanks and 4,400 armored vehicles."[179]

For the light infantry divisions holding the 'Saddam Line', however, the story was quite different. Central Command estimated that 65,000 Iraqi soldiers were taken prisoner.[180] Several different sources, given the benefit of post-war reconstructions, estimate that about 50,000 Iraqi soldiers were either killed or wounded.[181] Oddly, when one totals these two figures, it comes close to the strength of the fifteen Iraqi infantry divisions occupying the forward defenses (115,000 vs. 120,000). Two months before Iraq invaded Kuwait, one MIT analyst, Dr. Ahmed Hashim ". . . convincingly argued that about 70 percent of Saddam's front-line forces were Shiites, 20 percent Kurds. He called these forces Saddam Hussein's 'throwaway divisions'."[182]

Case Study Two: Logistic Sufficiency

Introduction

In Chapter Four, this thesis examined the battlefield function of logistics. The potential weaknesses of the supply function suggest that an adequate case study illustrating the value of quantitative decision aids would isolate a mission that went beyond its logistic means, either through a lack of supply, a lack of transportation, or an predictable increase in consumption rates. Additionally, while decisions concerning the logistical requirements of a mechanized army are almost completely dependent on quantitative tools, it appears that human friction still plays a significant role in increasing an already significant logistics burden. Give the above, and since this thesis seeks to explore the boundary between the moral force and quantification schools of thought, we will use the story of Kampfgruppe Peiper--a case study that pits a ruthless group of soldiers against the quantifiable consumption rates of their own vehicles on the north shoulder of the Ardennes counteroffensive in December 1944.

The methodology will seek to determine what Joachim Peiper knew about his mission, his organization, and his enemy. It will then apply quantitative decision aids against this body of knowledge to estimate Peiper's logistic status throughout his mission, in order to reach conclusions about the utility of such aids.

The Plan

Success on the north shoulder of the counteroffensive was critical to the German plan, since it represented the shortest distance to the counteroffensive's final objective. The Sixth Panzer Army, under Sepp Dietrich, was to strike northwest through this sector to the Meuse River and race for the port of Antwerp some 80 miles beyond, thus splitting the allied forces in northern France and the Low Countries and, simultaneously, depriving them of a major port of supply.[183] The secrecy of the planning was such that Peiper got his first indication of his potential mission some five days before execution from the 6th Panzer Army's chief of staff, SS-Brigadefuhrer Fritz Kraemer:

> On December 11, Kraemer approached him at the Liebstandarte's bivouac area near Euskirchen west of Bonn and asked him how long he thought an armored regiment would require to travel fifty miles (the approximate distance as the crow flies from German lines to Huy). Peiper apparently preferred empiricism to speculation . . . and took one of his regiment's Panther tanks on a night ride of the prescribed distance behind German lines. Although moderately colorful in the recounting, this excursion is of questionable value since the roads were superior to those that Peiper would encounter in the offensive, the distance to Huy over these roads was much greater, enemy opposition absent, and only one vehicle was involved.[184]

Like his experience in Russia, this anecdote illustrates Peiper's tendency of thinking in terms of the 'tip of the spear'.

The 12th Volks Grenadier (VG) Division, commanded by General Gerhardt Engel, was given the assignment of punching a hole in the US 99th Infantry Division's front through which Kampfgruppe Peiper would then exploit on its critical drive to the bridges on the Meuse.[185] For this breakthrough, Peiper was assigned ". . . the minor road running from Lanzerath through Bucholz, Honsfeld, Schoppen and Faymonville and known to the Germans as route D."[186] This specially selected route had fewer bridges than the others, and would eventually end at Peiper's objective--the bridge over the Meuse River at Huy , midway between Leige and Namur.[187] Although 'specially selected,' it was strangely a route unfit for large-scale armored vehicle movement and ". . . ran for long distances over narrow dirt roads which snaked through hilly and heavily wooded terrain, forest tracks that Peiper bitterly described later as ". . . fit for bicycles," and not tanks.[188] Additionally, much of Peiper's route was already degraded by the American traffic that had operated over it in the preceding months. It was over this route -- with close to a thousand mechanized vehicles -- that Peiper hopefully ". . .was to dash for Huy without regard for his flanks, avoiding likely opposition, and where possible bypassing it if encountered."[189] As part of the plan, the 3rd Parachute Division, following Peiper closely on foot would then peel troops off to face north and protect his supply routes.[190]

The Sixth Army plan was complicated by three other factors. First, the fact that

> . . . two trainloads of gasoline destined for the German attack force had not arrived. Peiper could, therefore, count on starting out with full fuel tanks but with no

> reserves and would have to capture large stocks of gasoline along his line of march . . . [191]

This did not seem as large an obstacle as it otherwise might have been, since Peiper had intelligence on what was assumed to be the U.S. 99th Division's fuel dump, located some 40 kilometers from Peiper's assembly area,[192] and a much larger dump, 30 kilometers deeper at Francorchamps. Second, Hitler had decreed death to any commander impinging on the route of another.[193] This, and the scarcity of good east-west routes, meant that the German armored spearheads lacked the flexibility to bypass resistance by taking alternate parallel routes around strong enemy resistance. Third, a debate had erupted during the planning of the operation concerning who was to make the initial penetration--infantry or panzer divisions. By January, 1945 ". . . a German Infantry Division had an authorized horse strength of 3,057 . . . and this would be a low estimate, as no account has been taken of the corps and army-level assets . . . "[194] supporting a single division. Thus, if the infantry led in the attack, the scarcity of routes through the Ardennes would mean that the following armored units would have to wait for over 1,400 horse-drawn carts, moving at a blistering five kilometers per hour, to arrive at their destination and clear the route. The armored commanders in the 6th Panzer Army recognized this flaw, but the plan remained to let the infantry lead, perhaps because of the close terrain of the Schnee Eifel.

On the eve of the great counteroffensive, Peiper summarized the operation in what we would describe today as the commander's intent:

> At a conference with his subordinate commanders . . . Peiper explained that, in view of the grave disabilities under which the Kampfgruppe would be operating, the only chances for success lay in the maximum possible speed, surprise, and the ruthless commitment of men and materiel. The leading elements of the Kampfgruppe were to stop for nothing and drive with single-minded purpose for the Meuse.[195]

Peiper's understanding of the situation and mission caused him to recognize its 'grave disabilities', yet he couched its chances for success not in terms of materiel, but in terms of human effort - speed, surprise, and ruthless commitment.

Peiper's Task Organization and Technical Data

Kampfgruppe Peiper was a heavily re-inforced SS Panzer Regiment, although most of its units were somewhat under strength. In addition to four tank companies of his own 1st SS Panzer Regiment, Peiper's command included a reinforced panzer grenadier battalion, a reconnaissance battalion, two companies of motorized combat engineers, a light Flak battalion, elements of the 1st SS Panzer Division's 501st Heavy Tank Battalion, and a company of foot mobile paratroopers. It consisted of approximately four thousand men, seventy-two medium tanks, almost equally divided between Mark IV's, Mark V's (Panthers), and thirty 68-ton Mark VI's: about 25 assault guns and self-propelled tank destroyers; an artillery battalion with towed 105mm howitzers; and around eighty half-tracks.[196]

The above represents only a count of the tracked combat vehicles. Using the tables of organization and equipment found in the U.S. War Department reference on the German Army, TM-E 30-451, Peiper's column would total 1,115 tracked and wheeled vehicles (excluding motorcycles). The exact vehicle strength quoted in the paragraph above implies that the units in Peiper's Kampfgruppe were at about 80 percent strength. For the purpose of this thesis, therefore, Peiper probably had a total of 800 vehicles in his convoy. In aggregate terms, using the technical data in FM-E 30-451 and operator's handbooks on the Tiger and Panther tanks, Peiper's Kampfgruppe was burning around 1000 liters per hour at the idle, about 1,500 liters per kilometer traveled on dry, cross-country routes. His force starts with an aggregate capacity of around 175,000 liters in its fuel tanks.[197]

German march techniques of the period prescribed a vehicle interval of 25 to 35 meters between individual vehicles.[198] With 800 vehicles, these intervals would have resulted in a column length of between 12 and 17 miles (20 and 28 kilometers). As Peiper calculated it ". . . his column would be about fifteen miles long and in the sharply compartmented terrain of the Ardennes, mostly road bound."[199] According to FM-E 30-451, Kampfgruppe Peiper would move at an average rate of 12 kilometers per hour during daylight and 7 kilometers per hour at night. It would be following an infantry division moving at around five kilometers per hour, day or night, possessing a march column length of about 30 kilometers.[200]

The Initial Calculations

Using the information above, the march computations in Appendix A and the logistics computations in Appendix B, Joachim Peiper and his staff should have come to several initial conclusions about their part of the counteroffensive:

1. Start Time. KG Peiper was following the 12th Volks Grenadier Division on Route D. This organization contained 1,466 horse drawn vehicles, and was supported by a Corps slice about half that size. Given a jump off time of 0600 hours, and barring any problems, the earliest Peiper could have gotten on Route D at Hallschlag is about 1500 hours that afternoon. The earliest he could expect to pass through the 12th VG would be six hours later.

2. Initial March Rate. Even after getting on Route D, Peiper would still be far back in a column of horse drawn vehicles moving at 5 kilometers per hour. At this rate, it would have taken Peiper two hours to march the distance from his assembly area around Blankenheim and then over two hours to close the 11 kilometer distance between his start point east of Hallschlag to his presumed passage point through the 12th VG west of Losheim.

3. The Route. Route D wound some 119 kilometers through the Ardennes. Peiper had to march 18 kilometers from his assembly area to the start point of Route D. It was not one contiguous route, but a patchwork of narrow improved roads, dirt roads and pasture trails. A majority of the route had been fought over recently, and

the U.S. Army was using (and degrading) major portions of the Peiper's Route D. Additionally, the Germans themselves had destroyed Peiper's first bridge during their retreat some months earlier. Although the 6th Panzer Army chose Route D because of its low number of bridges, if any one bridge became unusable, Peiper did not possess mobile bridging assets and would be forced off his route to seek another bridge. The weather had been overcast and rainy for a number of days, further degrading the route, and increasing the fuel requirements above normal.

4. Fuel Requirements. According to the gross fuel consumption figures quoted from operator's manuals, Peiper had almost exactly enough fuel to get to Huy (predicted usage was 168,900 liters and Peiper was carrying 175,000 liters) on a standard road march over a good cross-country route and without enemy interference. But Peiper's route was in poor shape and enemy resistance was guaranteed -- both factors would combine to effectively double his fuel consumption figures. Technical and historical consumption data described in Appendix B could have told Peiper that he would consume twice that amount over muddy roads in combat. While Peiper knew of at least two American fuel dumps along his route, there was no guarantee that they would be captured intact. Additionally, none of the three types of tanks in Peiper's column (Mark IV's, V's, and VI's) could make it Huy unrefueled. At his start point Peiper had enough fuel to go as far as Stavelot -- halfway to his final objective. Each two hour period spent at idle would shorten his range by about a kilometer.

Given all this, Peiper could have predicted that, if Route D was intact, he had enough fuel to go as far as Stavelot -- halfway to his objective of Huy. If he wished to conserve some fuel for a defense, he had to stop perhaps 20 kilometers sooner -- perhaps at Ondenval. With every unexpected flaw in Route D, with every hour spent idling or in combat, with every unexpected detour, his range became less.

Execution

Early in the morning of December 16th, Peiper moved to Engel's HQ east of Hallschlag to determine the exact moment that 12th VG achieved a breakthrough. Artillery preparation began at 0530 hours, with Engel's infantry moving forward one half-hour later.[201] The hoped-for quick advance was not to be:

> Peiper's mission ran into problems right from the start - The sixth Panzer Army's infantry divisions failed to effect an immediate breakthrough . . . Even when a gap was finally created, Peiper found his planned route of advance blocked by the horse-drawn transport of the 12th Infantry Division, thus forcing Peiper to make a rather lengthy detour. Thus, the two most important elements of the operation, time and speed, were lost in the Sixth Panzer Army's sector right at the outset.[202]

By early afternoon, Peiper was still at Engel's HQ; his column remained on a hair trigger with engines idling. The bridge south east of Losheim, which the Germans had themselves blown during their eastward retreat months earlier, could not be repaired due to the presence of the 12th VG horse-drawn artillery, which clogged the approaches to the bridge and prevented horse-drawn combat engineers from reaching it with their equipment. After an infuriating personal effort to clear the roads. Peiper ordered his lead vehicles to run down anything in their paths:

> All day he had waited, his tanks and half-tracks using up precious gasoline in traffic jams, and still no penetration to spring his column loose. In the end he had simply plowed his way forward, ordering his tank commanders, if they had to, to run down the horse-drawn artillery that was clogging the roads.[203]

Peiper reached the damaged bridge, briefly halting to find a bypass and then curse the lead element commander for his lack of initiative. An overland detour around the bridge was found and Losheim entered by forward elements of the Kampfgruppe after dark.[204] While in Losheim, Peiper received a radio message from 1st SS Panzer Division telling him that his second bridge (north west of Losheim) was unusable as well. The message went on to say that elements of the Third Parachute Division, in the next sector south, had achieved a small penetration at Lanzerath. Peiper was directed to detour southwest to Lanzerath before swinging north back onto Routed D at Honsfeld.[205] As he swung southwest on Highway N26 in the dark, one lead vehicle after another blew up. While the paratroopers had used this route 12 hours before in their advance on Lanzerath, they failed to clear the route of anti-tank mines. After several more hours of delay, Peiper chose the same technique he had used with the horse-drawn traffic earlier--he ordered his men to simply plow down the road. At 2300 hours, after losing 10 vehicles in the space of three kilometers, he burst into the Cafe' Scholzen in Lanzerath, screaming for the regimental commander of the 9th

Parachute Regiment, who lay asleep with his men on the floor. At this point, Peiper's formation had consumed close to 89,000 liters of gasoline--half of the fuel he started with in his assembly area. Peiper remarked later that, because of the conditions and delays of that first day's march, his fuel consumption rate was double that expected.[206] After 30 kilometers of infuriating approach march, he was just now reaching the American lines, and had 106 kilometers remaining to Huy.

After soundly cursing the commander of the parachute regiment for his failure to thoroughly reconnoiter his sector and complete the breakthrough, Peiper assembled an orders group and planned his own breakthrough attack for 0400 hours on the morning of the 17th.

Peiper's attack blew through Bucholz Station, two kilometers beyond Lanzerath, between 0430 and 0500 hours on the morning of the 17th. Peiper was moving fast now, exploiting the confusion in the American sector. Two kilometers farther, the Kampfgruppe entered Honsfeld at about 0600, where he rapidly captured a portion of the 394th Regiment trains, including 50 reconnaissance vehicles, half-tracks, and 80-2 1/2 ton trucks, but no fuel.[207] As Peiper headed for Bullingen, some three kilometers to the northwest, his column was strafed and suffered a number of losses, although the record does not reflect exactly what the losses were or how they impacted on Peiper's logistics.

Peiper reached Bullingen, captured the 50,000 gallon (190,000 liter) fuel depot established by the 2nd Infantry Division's

Quartermaster Company and began refueling before 0900.[208] The evidence is clear, however, that Peiper did not exploit this fuel dump completely. The lead elements of Peiper's column apparently did not stop to refuel at all, since Sgt. James Decker witnessed the first seven tanks, followed by 12 half-tracks, laden with troops, racing through--and beyond--the village.[209] Using 50 prisoners,[210] it still would take over three hours to empty the 10,000 five-gallon cans in the Quartermaster Company.

Peiper testified later that he was able to fill all of his tanks from this depot, but that heavy American artillery forced him to begin movement out of Bullingen between 0930 and 1000 hours that morning. Peiper's comment about fuel consumption earlier indicates that his tanks (MkIV's, V's, and VI's) had burned the gas required for 50 kilometers of normal cross-country travel. This means that they were all about half-full at this point. To top off only his tanks required about 10,000 gallons (38,000) liters at Bullingen. This figure agrees with the amount of gasoline physically transferable from 5-gallon cans by 50 men in the single hour available (approximately 13,000 gallons) before American artillery started impacting in Bullingen. Whether Peiper ordered his men load the remainder on his trucks, and whether his men would have been able to so under an artillery barrage remains unresolved at this point. Undoubtedly, Peiper would have questioned the terrified prisoners about the location of other fuel dumps in the depth of the sector. Peiper already had intelligence on the existence of the Army dump at Francorchamps, although not the exact location. If Peiper abandoned the rest of the gasoline at Bullingen, he did so with the prospect of capturing more in depth.

In the area of Bullingen-Honsfeld, Peiper dispatched four company-size patrols to conduct route reconnaissance. In each case, the patrols made round trips of around seven kilometers and returned with word that the route was either too poor, or that substantial U.S. elements blocked the way.

Upon exiting Bullingen, Peiper took the Bullingen-St.Vith road. At this Point, Peiper was again strafed and had to scatter his column into the woods on either side of the road. Peiper's column was so long ". . . that even as the first vehicles left Bullingen, others were still far to the rear . . . beyond Lanzerath."[211] Five kilometers out of Bullingen, Peiper divided his column in order to seize the Headquarters of the 49th Anti-Aircraft Artillery Brigade in Ligneuville in a pincers. The northern column, under command of Major Poetschke was to take the route Moderschied-Schoppen-Ondenval-Thirimont in order to enter Ligneuville from the north. Peiper took the southern route, Heppenbach-Ambleve-Kaiserbaracke. Peiper approached Ambleve around 12 noon on the 17th. He engaged a fleeing American unit and over-ran Ambleve by about 1300 hours.[212] Even with the fuel captured in Bullingen, he now had just enough gas to reach Basse Bodeux, some 56 kilometers short of Huy.

Peiper's northern column reached Ligneuville at 1330 hours on the 17th, engaged the service trains of Combat Command B, 9th

Armored Division and drove them to the north -- but the AAA Brigade managed to escape. The northern column then regrouped and waited in Ligneuville until Peiper's southern column began arriving at about 1630 hours. Upon his arrival, Peiper was informed that the 12th SS Panzer Division still had not reached Bullingen. He discussed this with his division commander, Major General Mohnke, and reached a decision to usurp the 12th's route at this point.[213] Peiper's column was still strung out on the bad roads, with long gaps between units.

At 1700 hours, Peiper's lead elements left Ligneuville for Stavelot along the same muddy route that the 49th AAA Brigade had escaped over earlier. The column reached the outskirts of Stavelot at about 1830, and immediately made contact with American tanks and infantry. Peiper, who had been awake since the 13th of December, decided to wait outside Stavelot, let his column close up, and attack in the morning.[214] He had 21 percent of his fuel remaining, and he was halfway to Huy.

When Peiper resumed his attack at 0800 hours on the 18th, he was able to cross the bridge over the Ambleve river thanks to the work of some of Otto Skorzeny's commandos, who disabled the demolitions the previous evening. The guards at the eight million liter Army gasoline dump on the Francorchamps road watched the firefight some 4 kilometers to their south. They then set the southern end of the dump on fire--and were making preparations to fire the remainder, but not a single German tank attempted to climb the hill to the fuel dump. Peiper was fixated instead on the bridges at Trois Ponts five kilometers to the west. He sent two tank companies ahead on a separate route to secure the three bridges ahead of his main column.

Peiper's overnight delay in Stavelot allowed the 51st Engineer battalion to prepare the main bridge in Trois Ponts for demolition. At 1115 hours, as Peiper neared, it went up in a cloud of debris. A nearby bridge over the Salm River was blown shortly after. Peiper had no choice but to turn north and try the bridge at La Glieze. As he turned, planes of the 365th Fighter Group and the 300th and 506th Fighter Squadrons attacked the rear of his column still transiting through Stavelot.[215]

At 1300 hours, Peiper crossed over the Ambleve at an intact bridge in Cheneux. Simultaneously, the fighter-bombers that attacked the rear of his column earlier at Stavelot finally worked their way up to the front of his formation. Peiper had to hide his column until ground fog halted the air attacks at 1600. This delay allowed engineers from the 291st Engineer Battalion to wire the next bridge at Habiemont, eight kilometers from Cheneux.[216]

At 1645 hours, Peiper's lead tank, a Tiger Royal, heaved into sight of the Habiemont bridge and fired a warning shot at the U.S. engineers who were just then connecting wire to the blasting machine. The Tiger's opening shot was answered by the destruction of the last bridge Peiper had to cross. Behind him, the 30th Infantry Division was counterattacking into both Stavelot and Malmedy. thus stopping the westward movement of the 1st SS Panzer Division.

Peiper now had neither the fuel nor the route to continue. He turned his column around and began to move back towards La Glieze, where he made a radio report early on the morning of the 19th informing MG Mohnke that he was ". . . almost out of fuel, he was low on ammunition, and he could go no further unless reinforced."[217] One battalion commander's Royal Tiger tank, the first of many, is abandoned, out of fuel, on the N33 highway between Stavelot and Trois Ponts.[218] Had Peiper fully utilized the fuel captured in Bullingen, he most certainly would not be out of gas here. He would have another 150,000 liters at his disposal. One by one, Peiper's vehicles run dry and, by the 23rd of December, Peiper and the survivors of his Kampfgruppe had to make their way on foot back to the German lines.

Case Study Three - Battle Outcome

Introduction

In Chapter Four, we explored the problems with quantifying battle outcome. The framework of understanding combat power developed by Brigadier General Huba Wass de Czege, and adopted by the U.S. Army, contains four primary variables--firepower, maneuver, protection, and leadership. Two of the most important variables, maneuver and leadership, are not currently conceptualized with the tool of quantification. Instead, these variables are though of in terms of heuristics such as 'It is better to attack in the enemy's rear or flank', and 'good leadership wins battles'. Two minor variables--firepower and protection--are quantifiable to some degree. While we intuitively feel this model to be valid, today's tactical decision maker still uses simple deterministic 'force ratio' calculations to attempt a good fit between ends and means.

The search for an appropriate case study was difficult. Since two of the variables were essentially unquantifiable, the appropriate case study could not include asymmetrical elements of either maneuver or leadership. In effect, the case study had to hold these two variables constant, and concentrate on the other two variables -- firepower and protection. Additionally, enough data on tactics, weapons effects, troop strength, and environment had to exist to allow the examination of several different methods of firepower calculation.

The case study selected was a portion of the battle of Fredricksburg in the American Civil War. While this era may be considered somewhat dated to today's tactician, enough data exists to analyze the firepower and protection variables. This battle contained very little maneuver, and no appreciable difference in leadership existed at the brigade and division level.

Because of the complexity of battle, this case study will be somewhat longer than the first two, and more technical data will be presented in the body of the study, as opposed to the appendixes. We will explore the tactics of the era, the physical effects of weapons used, and the plans and organizations of the opposing forces before examining the various battle outcome calculations.

Civil War Tactics

Starting from a common education (Mahan) and experience (Mexican American War), the military leaders of the Civil War developed the same doctrinal tendencies. Union and Confederate alike would rely on the tactical offensive, the belief that no line could withstand the properly applied 'arme blanche ' (the bayonet and saber), and the notion that rifles only ". . . exhibit their marked superiority when used by isolated marksmen".[219]

In effect, the tactics and doctrine of the American Civil War remained grounded in the technology of 1835, the year General Winfield Scott published his widely read, three-volume Infantry Tactics. At least ten official editions of Infantry Tactics were published between 1835 and the beginning of the Civil War, ". . . but the original work was never revised."[220]

Quantifying Firepower

To uncover the details about the effects of firepower, start with the casualty reports. From the above description of tactics, the average commander in this era would probably assume that in actual battle wounds from the bayonet and saber would account for a majority of the casualties on any Civil War battlefield. But analysis of the casualty reports available before Gettysburg revealed that only 0.05 percent of combat casualties were due to sword blows and about 0.1 percent of combat casualties were due to bayonet wounds.[221] Seven percent of the casualties were caused by large projectiles--cannon shot, shell and bomb fragments, grape and canister. Ninety-two percent of casualties in the Civil War were caused by small projectiles--musket, carbine, rifle, pistol and small missiles from shrapnel and canister.[222]

Within this major category of casualties caused by small projectiles, the two subcategories are casualties caused by small arms and artillery. The casualties inflicted by artillery in the Civil War have usually been minimized by historians. Perhaps one reason for this was the difficulty a surgeon had in distinguishing a canister or shrapnel wound from a musket ball wound, since both could be caused by spherical projectiles. Grant's campaign in the spring of 1864 recorded only six percent casualties from artillery, while at Malvern hill the Union artillery inflicted probably fifty percent of the Confederate loss. At Fredricksburg, at least twenty percent of the North's casualties were caused by Lee's gunners.[223] While casualties by artillery varied, a much more illustrative example of the difficulty in calculating battle outcome is found in the dynamics of the infantry and the rifle.

In order to adequately address the effect of firepower, we must first come to grips with a curious phenomenon -- the same one du Picq mentioned in the 1800's: "We shall learn . . . to distrust mathematics and materiel dynamics as applied to battle principles. We shall learn to beware of the illusions drawn from the range and the maneuver field."[224] We will explore du Picq's statement in terms of the two primary variables of firepower--rate and effect.

The 'illusions drawn from the range' were expressed by Cadmus M. Wilcox, a Government technician working in the Army's

Ordnance Department. He reviewed the status of the rifled musket in the late 1850's and remarked that well-directed rifle fire was 'irresistible' at 600 yards and still destructive at 1,000 or 1,200 yards.[225] Additionally, the standard drill-field rate of stationary fire for this period -- in both armies -- was slightly over three rounds per minute.[226] This rate of fire, coupled with the accuracy quoted by Wilcox, amounts to a considerable amount of firepower. In fact, had these figures held true in battle, each Union division appearing on the outskirts of Fredricksburg would have suffered almost complete casualties in a matter of seconds.

Obviously then, the other element in conflict is the actual performance of these weapons in battle. Figures on casualties and ammunition expended were often tallied and recorded after Civil War battles. From these historical, 'macro-level' records, the combat accuracy of Civil War rifles in actual battle required about 120 Confederate rounds for each Union soldier injured, and about 180 Union rounds for each Confederate injured.[227] This is between 33 and 50 times worse than the test-range performance of the weapon. In order to approach an accurate model of battle outcome, we must first explore this overwhelming difference between test range data and actual combat performance.

Starting with the Confederate figure of 120 rounds per Union casualty, we can explain away some of the inaccuracy--but not all. For instance, with every ten-round paper package of ammunition came two rounds (a buckshot and a bore cleaning bullet) which most soldiers usually discarded.[228] With this information, the number of rounds necessary to produce one Union casualty drops to 86. We also no` anecdotal evidence of soldiers simply throwing away excess packages of ammunition, which would also impact to some degree on the macro-level figures of rounds-to-casualties.

Training of the individual had a significant impact on subsequent marksmanship. Up to 25 percent of a unit's rounds could misfire, due to improper loading procedure, or manufacturing defect.[229] Marksmanship training was by no means standard in either army. The case of the 24th Michigan may be typical of Civil War marksmanship training:

> . . . it was sent to the front within a very few weeks of its formation in July 1862, and in its only recorded target practice during that time three men were wounded and one died of a heart attack . . . the Regiment's next target practice came some four months later . . . after this we learn of a resumption over a year later . . . .[230]

While the standard drill rate of fire was three rounds per minute, we know that after fifteen to twenty rounds, fouling causes the sustained rate to drop off to about half the standard rate.[231] Additionally, the physical punishment of these weapons on their owner was significant:

> . . . after undressing (I) found my arm all battered and bruised and bloodshot from my wrist to my shoulder, and as sore as a blister. I had shot one hundred and twenty times that day.

> My gun became so hot that frequently the powder would flash before I could ram home the ball, and I had to frequently exchange my gun for that of dead colleague.[232]

Both factors would combine to lower the rate of fire to something substantially less that what the drill manual called for.

Force Ratios

The rough method for calculating force ratios is to simply compare numbers of like items--in this case infantrymen and artillery pieces. A more detailed force ratio calculation would take factors such as weapons differences, tactical posture, troop quality, or empirical data into account. However, the more detailed the force ratio calculation becomes, the more contentious it becomes as well.

Weapons Differences. In 1863, not more than ten percent of all Union regiments were equipped with smoothbore muskets, as opposed to 35 percent for Confederate regiments.[233] While these statistics should reflect the number of shots needed to wound or kill one of the opposite number, they do not.

Tactical Posture. The table below summarizes several current approaches to adjusting force ratios through application of multipliers representing tactical postures:

TABLE 2

VARIABLES APPLIED TO TACTICAL POSTURE

	ST100-9(91&2)	ST100-9 (89)	Dupuy	3rd ID (91)
Prepared Defense	x3	x2.5	x1.5-1.6	x3
Hasty Defense	x2.5	12-24hrs=x1.3 24-48hrs=x1.5	x1.3	x2.5

From the macro-level ammunition data above, one can perhaps state that a Confederate unit was about 1.5 times more accurate than a similar Union unit. T. N. Dupuy compared the battlefield performance of both armies and found that a Confederate unit was 1.47 times better at producing casualties.

Finally, we note that the average casualties per battle or campaign throughout the Civil War was around 20 percent.[234] Again, this was an example of the existing statistics that both sides could draw on by the time Fredricksburg was fought.

Confederate Plan

The Confederate plan called for Longstreet's Corps, consisting of the five divisions, to conduct a deliberate defense of the ridge line west of Fredicksburg. Burnside's indecision allowed Longstreet and his men over three weeks in which to improve and fortify an already naturally strong position. All five of the divisions had time to rehearse, adjust, and entrench in order to counter every enemy move after the Federals crossed the Rapahanock River.[235] The most important piece of the defense, as it turned out, was the sunken road:

> Cobb's Georgia brigade and the 24th North Carolina Volunteers of Cooke's brigade manned the sunken road with its protective four-foot stone wall, both of which were invisible to the attackers, who had no idea what a formidable obstacle stood in their way . . . . These units, in preparing their reception for the Federals, formed two successive lines in their narrow, protected causeway so that a continuous band of musket fire could be laid down on the attackers, one line loading while the other fired.[236]

Lee himself had the time to carefully select gun positions across the battlefield -- One artillery battalion commander in Longstreet's Corps, declared before the battle that the open fields between Fredricksburg and the ridge were so thoroughly targeted that ". . . not even a chicken could live to cross."[237]

Confederate Organizational and Technical Data

Three of Longstreet's divisions would take part in the action at Marye's Heights: Anderson's Division had 9,373 soldiers, McLaw's Division had 9,285, and Ransom's Division had 4,394 soldiers assigned.[238] Out of this strength, a total of 6,000 infantry men and 20 artillery pieces would participate in the battle of Marye's Heights.[239]

Union Plan

The attack on Marye's Heights would be conducted primarily by General Sumner's 'Right Grand Division', consisting of the Corps of Couch and Willcox. Sumner was slated to take the town of Fredricksburg and then attack the Confederates on their ridge position behind the town.[240] Instead of giving clear, and concise orders, Burnside is reported to have given long, rambling and vague instructions. His subordinate commanders and staff officers disagreed with his plan nearly from the moment of inception:

> In reply to a casual inquiry as to what (he) thought of the plan . . . just outlined, [General Rush C.] Hawkins replied, "If you make the attack as contemplated, it will be the greatest slaughter of the war; there isn't infantry enough in our whole army to carry those heights if they are well defended." Colonel J.H Taylor of Sumner's staff added, 'The carrying out of your plan will be murder, not warfare."[241]

Burnside's plan called for Franklin to maneuver Lee's right into an untenable position and then, at the appropriate time, he would give Sumner to the north the go-ahead signal to push only two divisions in the direction of Marye's Heights.[242]

Union Organizational and Technical Data

Sumner's 'Right Grand Division' consisted of two corps and 31,659 men. Couch's Second Corps possessed a strength of 15,383 soldiers, and Wilcox's Ninth Corps had 13,578.[243] In the attack on Marye's Heights, Sumner would be reinforced with divisions from two other corps. The total federal strength that assaulted Marye's Heights would eventually exceed 40,000 men.[244]

Initial Calculations

Several different methods will be used to calculate battle outcome. As discussed above, the most simple method is a straightforward comparison of numbers. The second method uses both empirical performance data and values for tactical dispositions to modify the initial straight count. The third method uses the simple firepower model developed in Appendix C (The 'Trans-Mech' Model)--a comparison of accuracies, rates of fire, distance and time exposed--to reach conclusions about the soundness of Federal decisions made at Fredricksburg.

Straight Comparison. Using the straight comparison method, Sumner enjoyed nearly a seven-to-one ratio in combat power. This is misleading however, because the full weight of his 'Grand Division' was not applied at the same time. Rather, its attack was spread across an entire afternoon. The largest mass that attacked Marye's Heights at once was two divisions, resulting in an operative ratio of two-to-one.

Modified Comparison. Using this method, the number of Confederate defenders is first multiplied by a modifier representing the aggregate advantage of materiel, training, leadership, etc. In this case, we assume that a Confederate unit was able to inflict 1.5 times the number of casualties it suffered. This number is then multiplied by a number representing the added strength of a prepared defense, (in this case -- 2.5):

$$\text{Confederate Strength} = 6{,}000 \times 1.5 \times 2.5 = 22{,}500$$

This number (22,500) represents the equivalent strength of the Confederate force on Marye's Heights. To overcome this, Sumner would need at least four divisions attacking at once.

The 'Trans-Mech' model, developed in Appendix C, takes firing rates, accuracies, distances, and exposure times into account in order to present the decision maker with a graphic representation of the opposing physical potentials of fire. If this results in a depiction of disadvantage, the decision maker is prompted to search for a 'transition mechanism', or set of mechanisms, that will tend to upset his opponents firepower potential.

In order to use the Trans Mech model on Fredricksburg, some basic accuracy data must be calculated. The data from the 1854 Harper's Ferry tests for standing volley fire is used as the basic Probability of Hit data.[245] This accuracy is then decremented by battlefield empiricism in the form of Paddy Griffith's figures, and adjusted for the rounds normally discarded upon issue. The difference between these two accuracy curves is significant--it represents firm evidence of the phenomenon du Picq warned his readers about. In fact, on the graph below, a logarithmic scale had to be used, because the difference between the test range and actual combat was two orders of magnitude.

We have already established that the regulation rate of stationary, volley fire was three rounds per minute--decreasing to one and one-half rounds per minute after about twenty rounds due to bore fouling. There were 6,000 Confederate soldiers waiting behind a stone wall 1,000 yards long--about six men per yard--waiting with rifles loaded. Each Union division had perhaps 6,000 men, and normally, while on the move, only the leading rank of perhaps 400 men could fire while still in formation.

The Union formations marching up Marye's heights toward the stone wall would move at the 'quick time' -- 110 steps per minute -- and cover, over that terrain, perhaps 100 yards per minute. It was around 600 yards from the western edge of Fredricksburg to the stone wall, and it would take each Union division around six minutes of movement -- uphill and exposed -- before they could hope to dislodge the Confederates from behind their wall.

For troops on the march and in formation, it was rare to get more than one shot before attempting the bayonet charge.[246] While the Union and the Confederacy shared similar armaments, the Confederate soldiers behind the four foot stone wall on Marye's Heights offered an 80 percent smaller target, with a corresponding decrease in the Federal Probability of Hit for each Shot Fired.

The Trans Mech model multiplies the number of weapons by the <u>combat</u> accuracy of the weapon and the rate of fire. In the Confederate case, the figure below illustrates the normal casualty-producing potential of the 6,000 Confederates behind the stone wall:

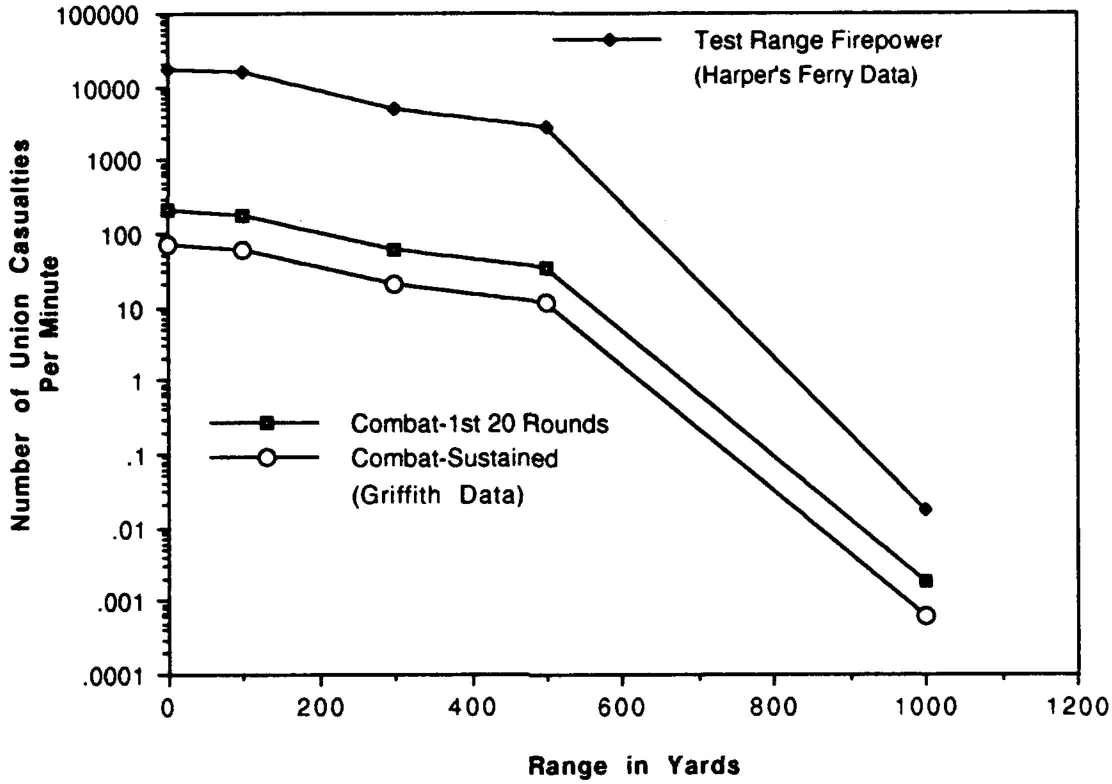

Figure 4. Calculation of Simple Firepower

Figure Three shows that the Confederate infantry behind the wall on Marye's Heights had the potential to wound or kill a total of between 300 and 700 Union soldiers between the western edge Fredricksburg and the stone wall, depending on how fouled their weapons were.

With the same methodology, each Federal division had the potential to cause four Confederate casualties, if they fired once before the bayonet assault.

The Trans Mech model, however, does not predict the battle outcome. Instead, it indicates to the decision maker where lopsided firepower potentials exist, and suggests that another technique should probably be used. In this case, perhaps Burnside could have conducted an attack at another location, a night attack, or an attack in the early morning fog.

Using the Straight Force Ratio Comparison Method, Sumner could have taken the heights with two divisions in the planned frontal assault. Using the Modified Force Ratio Comparison Method, Sumner needed at least four divisions in a frontal assault. Using the Trans Mech Model, Sumner needed to find another way to attack Marye's Heights

Execution

At 1200 hours on the morning of 13 December, 1862, the brigades of French's Division exited from the shelter of the western edge of Fredricksburg and began moving up the long open slope towards Marye's Heights and the stone wall. As they departed the cover of the buildings, Confederate artillery began to engage them at long range. Amazingly, the guides of the leading brigade managed to plant their guidons within 100 meters of the stone wall. Perhaps encouraged by this sight, the lead brigade advanced through a withering fire to a distance of sixty yards--at which point ". . . flesh and blood and courage could take no more . . ."[247] The remainder of French's Division that followed met essentially the same fate, leaving a high-tide mark forty yards from the Confederates of Cobb's Brigade.

At this point, the three Confederate division commanders, McLaws, Ransom and Anderson, could see other Federal brigades forming up on the western side of Fredricksburg. McLaws quickly sent additional regiments into the sunken road to reinforce Cobb's men, who set up four relays of infantry to accelerate the rate of fire. Hancock's division came next after French's, and ran into this accelerated firepower. Hancock's last charge came within forty yards of the stone wall. In the space of a single hour, two Federal divisions had been destroyed. The open slope between the edge of town and the stone wall was littered with 3,200 casualties.[248]

General Couch, the Federal Corps commander, watched the slaughter of his first two divisions from the cupola of the town's Court House. He now had a better idea, one that would send his last division--Howard's--around to the right in order to flank the stone wall. At about 1300 hours Howard began across the open slope, angling to his right in preparation for a flanking attack. Without prior reconnaissance, however, Howard had no way of knowing that his intended route was marshy ground. This had the effect of channelizing his division right back into the reinforced Confederates behind the wall. Nine-hundred casualties later, the remnants of Howard's shattered division filtered back down the slope towards Fredricksburg.[249]

Instead of abandoning this line of attack, Burnside--who was isolated from the carnage in his command post back across the Rapahanock--kept sending orders to continue the attack.[250] Four more divisions, those of Humphries, Sturgis, Griffin, and Getty were ordered into the meat grinder before the battle ended. Each met with the same fate as the first three. More would have been committed the next day, had it not been for the unanimous dissent of Burnside's subordinate commanders at a meeting later that night. The final count of Federal casualties in front of the stone wall totaled 6,300--almost as many as Picket would lose six months later in a similar situation at Gettysburg.[251]

After nightfall, the survivors and walking wounded of those seven divisions made their way safely down the slope and back into Fredricksburg. Shortly before midnight, Sykes' Division formed up and marched to within fifty yards of the stone wall, where it silently bivouacked without casualties. As the sun rose the next morning, and the fog cleared, this division was trapped under the accurate Confederate fire. That evening, after nightfall, Sykes' division formed up and marched back down the slope again without serious loss.[252]

CHAPTER SIX

ANALYSIS OF CASE STUDIES

Introduction

This chapter analyzes the case studies with two goals in mind. First, we must determine whether actual battlefield phenomenon differed from the decision aids presented in Chapter Four and the appendices. If a substantial difference existed--one that would have caused a poor decision to be made in the case study--then this chapter must analyze why, and draw conclusions about the utility of such decision aids. Second, if common patterns of difference or similarity between the decision aids exist, we want to isolate them in order to identify significant trends.

As mentioned before, the general method will be to take these three case studies and, in the analysis, adjudicate the resulting meeting of the 'irresistible moral force against the immovable physical object'. This process has the added benefit of illuminating secondary insights which, until this point, have remained obscured.

Analysis of Desert Storm Movement

This case study was selected for two reasons. First, it showed how simple quantitative aids can assist in aiding decisions concerning movement. Second, and more important, it brought the two schools of thought developed in this thesis into direct confrontation with one another. The moral force can take on many shapes, but in the form of the Iraqi retreat, it appeared to take on the most elemental form of desperation. Certainly, by the time the retreat was ordered on February 25, a vast majority of the Iraqi Army needed no additional prodding to move quickly to the north. Yet, the Iraqi Army was restrained by both its means of transportation, and the route structure over which their fear of the desert forced them to move.

VII Corps also faced physical restraints. Its cross country speed was around ten kilometers per hour, and it needed a large quantity of fuel every eight to twelve hours. These factors could not and did not change, despite the prodding by an irate theater Commander. By the time of the cease fire, 1st Armored Division had no fuel reserves left.[253]

We were interested in the two distinct march times in this case study: the first is the time needed to evacuate the Iraqi Army over the existing route structure, the second is the time VII Corps required to cut off the Iraqi retreat at Basrah. Using the initial calculations in the form of Figure Five (below), we can make some observations about the plan to 'shut the door' on the retreating Iraqis.

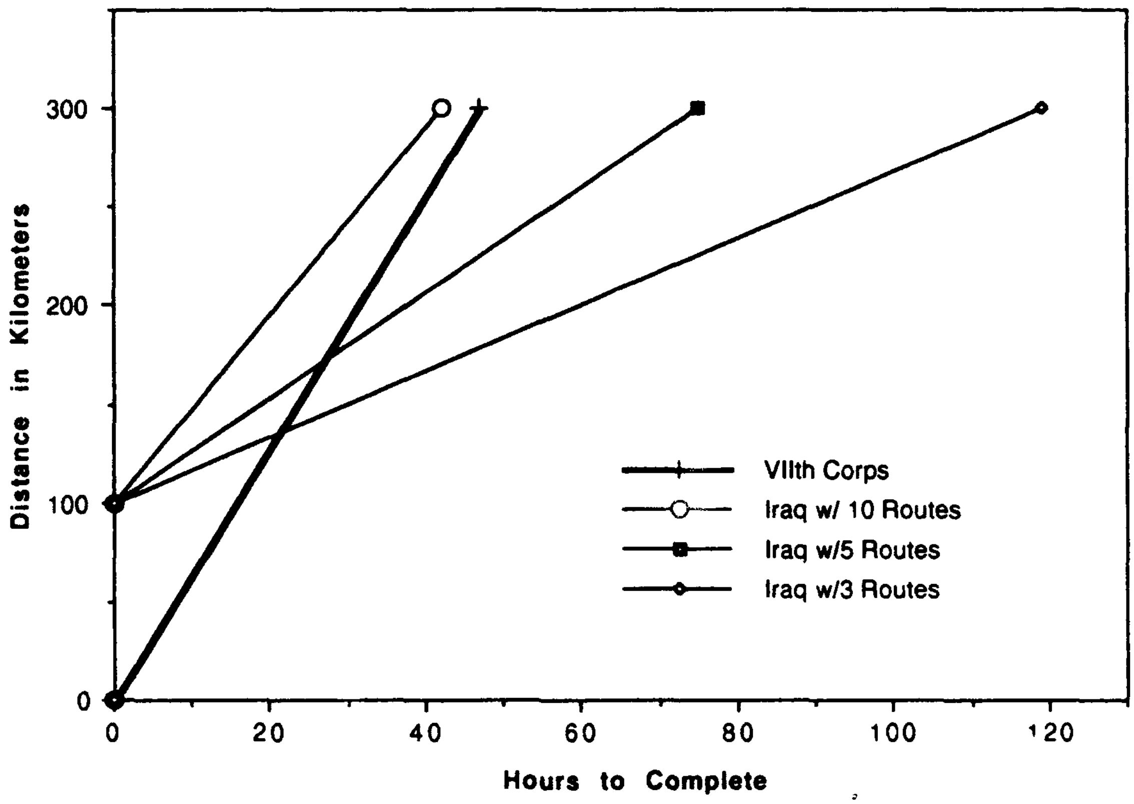

Figure 5. Analysis of Calculated Movement Rates

With all ten routes intact, Iraq could beat the VII Corps out of the KTO with all its mechanized and motorized elements. With five intact Iraqi routes, VII Corps would perhaps cut off two-thirds of Iraq's mobile units. With only three Iraqi routes, VII Corps would cut off over half of Iraq's mobile power. This means that part of the campaign plan had to address the interdiction of some, or all of these routes.

The air assault of the 101st Airborne Division into AO Eagle was designed from the outset to cut Highways One and Eight -- thus depriving Iraq of five potential routes of escape. XVIII Airborne Corps was tasked to cut the causeway (two routes) over the Al Hammar with the 24th Infantry Division -- but that would not be possible until D+3 at the earliest. The highways running along the Shatt Al Arab (three march routes) could have been possibly cut with another air-assault. Air interdiction could also have cut these last five routes.

Both the execution of the plan and the Iraqi response differed from the initial calculations. VII Corps executed two planned halts--once on the evening of the 24th, and again on the evening of the 25th. The Iraqi order for the withdrawal did not come until the afternoon of the 25th. With the addition of this information, Figure Four (above) takes on a slightly different form:

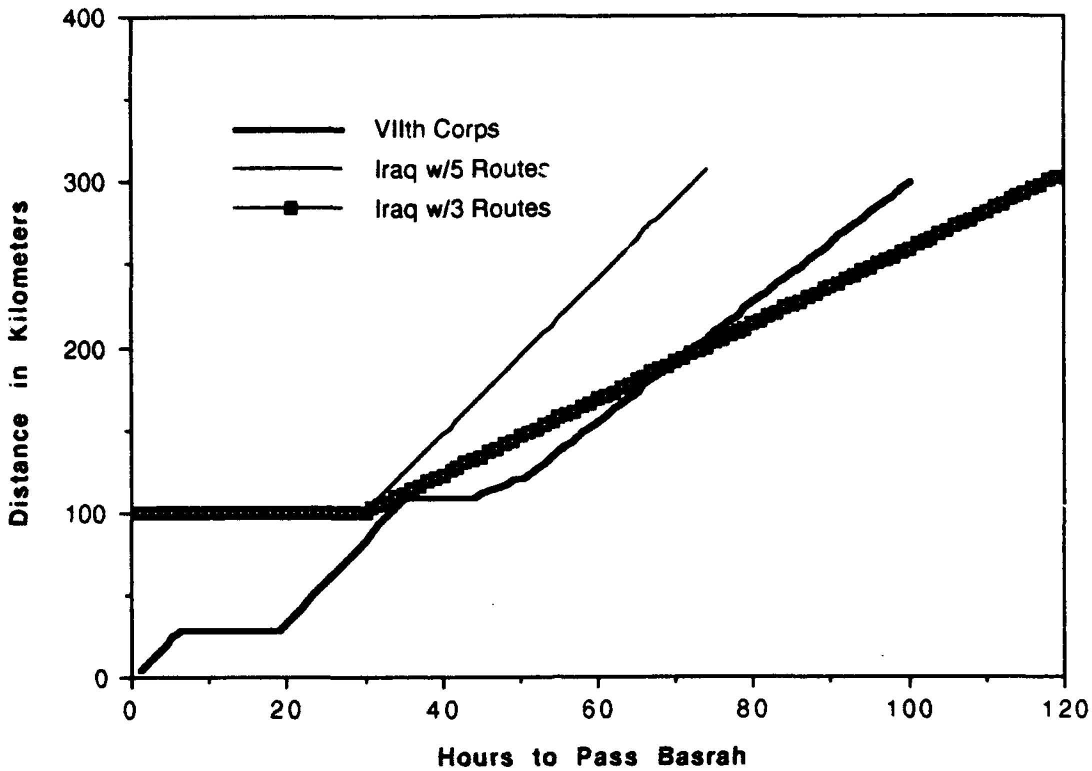

Figure 5. Analysis of Movement with Halts and Delays

On the basis of this data, only the three-route situation offered hope that the VII Corps could have trapped even a small portion of the Iraqi Army south of Basrah. Without the air interdiction campaign to close these routes--and keep them closed over time--the bulk of Iraq's undamaged mobile forces had a good chance of escaping.

Recall that the transportation throughput bottleneck was the town of Basrah itself. Additionally, the cease fire of the 28th meant that VII Corps could neither reduce the Basrah pocket, nor use artillery, air, or helicopters to close the final three routes. The cease fire line was five kilometers west of the Al Hammar causeway, and the cease fire rules of engagement allowed only self defense. This meant that, until the Iraqi cease-fire violation at the causeway on the second of March, the 24th Infantry Division could not shut the causeway routes. By the evening of the 27th, Iraqi engineers had cleared the wreckage off the causeway, and J-STARS images confirm that traffic continued to move until the second of March.

Additionally, J-STARS shows vehicle traffic continuing to flow up the Shatt Al Arab highways from Basrah for days after the cease-fire. From the 26th on, a combination of bad weather and heavy oil smoke prevented an air interdiction effort sufficient to stop the flow of Iraqi vehicles over these five routes.

The assumption that drove the first case study was that the Iraqis, despite their blind panic, still could not get out of the KTO any faster than the route structure and means of transportation would allow. At the same time, however, we note that, despite apparently vigorous prodding by GEN Schwartzkopf, VII Corps was restricted in its march time by very similar factors. Had CENTCOM or 3rd Army recognized this in time, a more concerted effort would have been placed on dropping the bridges over the Euphrates and Shatt Al Arab before the ground campaign, as opposed to trying to stop the flow in the poor weather and oil smoke after JSTARS picked up the retreat.

The initial calculations revealed that the 3rd Army plan could not, by itself, prevent the Iraqi evacuation of the KTO without some changes. The VII Corps plan could have been changed to keep the Corps moving continuously. This, however, would have required a major readjustment of the logistics--especially fuel--in the Corps march order. In essence, the Corps would have to move every gallon of fuel required for the whole fight forward in its march order. It would take several days to re-adjust the Corps plan--it probably could not be done as easily or as quickly as GEN Schwartzkopf indicated in his biography.

Another option would be a concentrated air interdiction effort--to include air-delivered mines--aimed at the five routes out of Basrah. If the plan depended on this option, however, it might also have failed due to the weather and visibility problems on the last two days of the war.

A third option could have included either an air assault or a parachute drop of the 82nd Airborne on G+2. This was an option that apparently considered, but ruled out as high-risk.

While it is true the Coalition captured, killed or wounded a large number of Iraqi soldiers, the evidence suggests that most of these were the foot-bound, 'throw away' infantry that Hussein had little concern for in any event. Thousands of Iraqi vehicles were destroyed during the war, but thousands got away as well.

This case study illustrates that relatively simple quantitative decision aids can increase the quality of decision making--even at Corps and echelons above corps. In this case, a computation of the march times of both forces accurately revealed an inability to trap a majority of Iraqi mobile forces in the KTO. A quantitative analysis of the route structure pointed out bottlenecks and critical points to address in the battlefield shaping phase of the campaign.

Analysis of Kampfgruppe Peiper and Logistic Sufficiency

This particular case study was selected for two reasons. First, it showed how simple quantitative aids could have assisted in aiding decisions concerning logistics. Second, and more important, it brought the two schools of thought developed in this thesis into direct confrontation with one another. The moral force can take on many shapes, but in Joachim Peiper it was brutal, relentless, well trained and experienced. Yet, he commanded a completely mechanized unit whose machines performed to a quantitative standard--whether he realized it or not. Despite his virulent Nazi ideology, despite the desperate nature of his mission, he simply could not cajole, encourage, or threaten a machine to go one meter farther without fuel.

What could the German Army have done to change either the logistic conditions or the tactical mission of KG Peiper? B.H.Liddell Hart interviewed one of the Army Commanders, Hasso von Manteuffel, after the war:

> The plan for the Ardennes offensive was drawn up completely by O.K.W. and sent to us as a cut and dried 'Fuhrer order' . . . .Rundstedt told me: "When I received this plan early in November I was staggered. Hitler had not troubled to consult me about the possibilities . . . no soldier believed that the aim of reaching Antwerp was really practicable." The worst deficiency of all was in petrol. Manteuffel said: " Jodl had assured us there would be sufficient petrol to develop our full strength and carry our drive through. This assurance proved completely mistaken. Part of the trouble was that O.K.W. worked on a mathematical and stereotyped calculation of the amount of petrol required to move a division for a hundred kilometers.

> My experience in Russia had taught me that double this scale was really needed under battlefield conditions. Jodl didn't understand this. Taking account of the difficulties likely to be met in a winter battle in such difficult country as the Ardennes, I told Hitler personally that five time the standard scale of petrol supply ought to be provided. Actually, when the offensive was launched, only one and a half time the standard scale had been provided. Worse still, much of it was kept too far back, in large lorry columns on the east bank of the Rhine. Once the foggy weather cleared, and the Allied air forces came into action, its forwarding was badly interrupted." The troops, ignorant of all these underlying weaknesses, kept a remarkable trust in Hitler and his assurances of victory. Rundstedt said: "The morale of the troops taking part was astonishingly high at the start of the offensive. They really believed victory was possible -- unlike the higher commanders who knew the facts.[254]

This illuminates several key elements of the struggle between the two schools of thought. First, it points out that a recognized disparity existed between the quantitative decision aids utilized by Jodl's level of command and those used by the field commanders. Manteuffel points out the organizational problems caused by competing sets of quantitative decision aids. Perhaps Jodl had no choice but to use the lower consumption figure to superficially join ends with means and appease Hitler. Yet, clearly, had the decision aids correctly reflected the logistical shortcomings, the rational man would never have launched the counteroffensive in the first place.

Second, it shows that soldiers and even smaller unit commanders can be motivated to give 100 percent effort and even to expect victory, when the quantitative analysis predicted something far less. Of all other factors, this is the most telling because it points out that both the quantitative and the moral force schools must be in balance to achieve the desired end. In a technological world, moral force without logistical (quantitative) support ends in something less than desired. Logistical sufficiency with no moral force to exploit it must also be considered a waste.

Third, Manteuffel's commentary illustrates the need to accurately collect and analyze combat logistics in a true OR mode. Had this been done early in the war, there would have been no argument between the field commanders and Jodl. Quantitative aids are useful when they are accurate, but become dangerous when used as political devices.

In a command climate such as Hitler's, where so much hinged on an assumed racial, moral, or philosophical superiority, the school of moral force held considerable, if not overwhelming, sway. In this climate, the SS elite--keepers of the sacred German cultural superiority--could not balk at an order, no matter how far fetched. Their belief in the superiority of the moral force was the source of their power and, as in the case of Peiper, their eventual defeat.

Analysis of Fredricksburg and Battle Outcome

This case study points out three important areas dealing with the thesis. First, the clear evidence of excellent military judgment without the use of quantitative decision aids. Second, the disparity between test range data and the actual combat performance of a weapon. Third, that quantitative aids, used with common sense, could have prevented the attack altogether.

Clearly, before the attack, Burnside's subordinate commanders recognized the futility of attacking Marye's Heights. To their credit, they had recognized the disparity between the tactics used in the Mexican-American war, and the actual battlefield conditions of 1862. This sort of evidence lends credibility to the use of military judgment alone. Burnside's commanders needed no quantitative aid to tell them that the next morning's attack would be close to suicide.

Using the test range data, the Federal divisions should have simply 'vaporized' after exiting the west edge of Fredricksburg. The fact that they did not and, in some cases, were able to get to within 60 yards of the wall and retreat with over half of their strength means that there is something missing from the materiel tester's understanding of the conditions of battle.

Other factors made the battlefield use of the weapon much more inaccurate than the test range results indicated. Among these reasons were the human dynamics of fighting in formation, misfire rate, poor training or panic -- causes never really testable on the rifle range. After the first few volleys on either side during most Civil War battles, smoke began to obscure the battlefield. Soldiers shook from fear, from the effects of the environment, and from the nearby explosions of musketry and cannon. Men were spattered with gore, injured from pieces of other bodies traveling ballistically; primer caps failed to fire; powder was often damp. At 600 yards, less than two-tenths of one degree separated a casualty-producing shot from one that went high or low. The concussion of a neighbor's rifle would cause one's rifle to jump whole degrees. In short, a lot could (and did) go wrong between the pull of the trigger on the test range, and the impact of a minie bullet on a real enemy.

The 'Trans Mech' Model used test range data, decremented by battlefield data, to predict between 300 and 700 casualties for each Federal formation that climbed Marye's Heights from rifle fire alone. If these same formations had to retreat under the same conditions, these casualty figures would nearly double The Union divisions (5,000 soldiers each) that fought in front of the stone wall lost, on the average, 948 soldiers that day. On the average, 20 percent of these were due to artillery, leaving 758 casualties due to rifle fire. Hancock's division left its high-tide mark of blood within 40 yards of the wall, and was highest on the casualty list with 2,029 lost. The divisions of French, Sturgis, Howard, Humphreys and Griffin each lost between 900 and 1100 soldiers. Later, at the end of the day, the divisions of Sykes and Getty attacked over the bodies left behind by 5 other divisions. Perhaps the gore beneath their feet took some of the edge off their attack, for these two divisions lost between 200 and 300 each before turning back.[255]

Conclusions

In each of the three case studies, the use of quantitative decision aids could have qualitatively assisted the decision maker. Additionally, the mathematical constructs of battlefield phenomena, once tuned by battlefield data collection and analysis, show no marked divergence from reality. In the case of Desert Storm, 3rd Army could have predicted that, while VII Corps could have cut off a majority of Iraq's foot-mobile infantry, it probably could not cut off a large portion of Iraq's mechanized strength. This might have prompted 3rd Army to insist on a different air campaign--one that concentrated sufficient forces on the escape routes out of theater. In the case of Kampfgruppe Peiper, the use of quantitative aids could have prompted Peiper to more fully use the gasoline he captured en route. Peiper's superiors could have certainly benefited from a quantitative reality check before launching the counteroffensive in the first place. In the case of Fredricksburg, Burnside could have used quantitative aids to avoid the attack on Marye's Heights. Certainly, the Federal divisions that attacked possessed the requisite moral force in order to proceed with 50 yards of the stone wall. What they lacked was the physical possibility to carry the position, given the density of Confederate firepower in front of them.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

Introduction

In the First Chapter, this thesis identified a goal--to determine if quantitative decision making aids have utility at the tactical level. In order to reach this goal, Chapter One also outlined two subordinate issues which are essentially opposite sides of the same coin--one has to determine which battlefield phenomena are subject to quantitative examination, and which battlefield phenomena defy quantification. In order to better attain this goal, Chapter Two proceeded to trace the history of quantitative decision aids in war in order to isolate the basic schools of thought concerning quantification. In the process, Chapter Two also identified some important secondary trends that impact on the issue. Chapter Three examined different research methodologies and settled upon an analysis of cases studies, which brings with it some advantages and disadvantages (like any other method). Chapter Four described some basic battlefield functions which, arguably, have remained constant over the phenomenon of war. Additionally, Chapter Four discussed the basic quantitative tools which are commonly used to conceptualize each battlefield function. Chapter Five took three of the battlefield functions, and presented three matching case studies that focused on the competition between the moral and quantitative schools of thought. Chapter Six analyzed these case studies to determine the utility of quantitative aids in each.

This Chapter will try to fuse this information into a coherent whole in order to accomplish three objectives:

1. Answer the primary and secondary questions of this thesis.
2. Outline the dominant trends which continue to have an impact on both schools of thought.
3. Project where we need to go from this point.

The Primary and Secondary Questions

The analysis of the case studies show that quantitative aids do indeed have significant utility at the tactical level. However, their utility differs from substantial to only cautionary, depending on which function we examine. In the more mundane battlefield functions of movement and logistics, the use of quantitative aids provides the decision maker with a stable, enduring framework for conceptualizing, predicting and controlling the function itself. This is largely due to the fact that human friction, while always present to some degree in these functions, is not nearly as powerful as its combat equivalent.

In the area of battle outcome, we note that combat power is a complex relationship among leadership, firepower, maneuver and protection. While the moral force school has long held that the power of humanistic elements are omnipotent and unlimited, this point does not hold true for two important reasons. First, the moral force cannot increase the performance of weapons beyond their engineered limits. Second, the capacity of man to inflict destruction on his fellow man with conventional weapons appears to be a distribution with a definite central tendency. Additionally, while leadership is identified as the most important variable of combat power, the ability of any army to produce uniformly outstanding leaders capable of uniformly superior results in combat has always been a goal--never a reality.

Dominant Trends

The Use of Operations Research

When military judgment fails, as it sometimes does when calcified by long periods of peace, rapid technological advance, or by recent victory, the whole system falls back on quantitative methods to at least establish a baseline to use in revising existing heuristics. Important trends--unadressed by conventional military judgment--have been illustrated using quantitative tools. In this light, the use of quantitative tools will continue to have utility at all levels of war. However, problems continue between the tactical decision maker and the OR scientist.

The use of OR is, almost by definition, limited by the scope of the phenomenon and the accuracy of data collection. One must be very conscious and careful is selecting the measure of effectiveness used in OR. Mistakes in selecting the appropriate measure of effectiveness can have consequences ranging from wasted effort in combat (as in the case of convoy protection) to inadvertent destruction of the moral power of an army (as in the case of body counts). As a corollary, OR must avoid the mode where the success of the operation is couched in 'input terms', such as number of sorties flown or tonnage dropped, for they may have little to do with the desired output. Whenever a quantitative aid is developed and made 'official', it should be used with a critical eye.

Without an operation, there is no OR. One may argue that, in an era of decreasing defense expenditures, a scarcity of full scale maneuvers, environmental and political restrictions of exercises, that the required data base is disappearing just when the army must again come to grips with rapid technological trends.

We also note a continuing trend for the ORSA community to drift further away from the tactical part of the army. On 17 November 1992, Mr. Walt Hollis, the Deputy Under Secretary of the Army for Operations Research, warned that "Operations research could go the way of the dinosaurs if we are not careful."[256] One contributing factor could be the continuing intellectual prostitution of Operations Research by the salesmanship techniques of Systems Analysis. The 2,300 active members of the Military Operations Research Society (MORS) fall into several broad categories: Military officers on staffs, DoD civilians, and civilian contractors. Not one MORS member is listed as an active-duty officer in a tactical unit. Additionally, the largest single group (by far) of active-duty Army officers with Functional Area 54 (Operations Research) is assigned to the personnel management office--not to a tactical unit.

This is an alarming divergence, given the original wartime charter of the Operations Research staffs of WWII:

> The main field of their activity is clearly the analysis of actual operations, using as data the materiel to be found in an operation room, e.g. all signals, track charts, combat reports, meteorological information, etc. . . such analysis. . .if done at all, must be done in or near operation rooms. The work of an Opeerational Research Section should be carried out at Command, Groups, Stations or Squadrons as circumstaces dictate. . . Experience over many parts of our war effort has shown that such analysis can be of the utmost value, and the lack of such analysis can be of the utmost value, and the lack of such analysis can be disastrous.[257]

Soldiers

In case studies two and three, the quantitative tools predicted mission failure. Yet, in both cases, the soldiers at the lower levels continued to be motivated and have faith in their leadership. Peiper's soldiers continued past their rational culminating point in terms of fuel. Federal soldiers of seven divisions kept climbing up Marye's Heights, taking care not to look to closely at the sea of gore beneath their feet. Perhaps this represents the true role of each school of thought. The moral force school ensures that the soldier is motivated. The quantitative school ensures that the moral potential of the soldier is not squandered due to lack of adequate planning.

Test Range vs. Battle Field Empiricism

In Case Studies Two and Three, we noted the phenomenon of test-range data that was modified by actual combat statistics to produce a m... accurate quantitative tool. One of the recurring trends we note is a conflict between these two different types of quantitative data. The first is the type of number that comes from the test range. The second is the type of number that comes from actual use or operation in combat. To date, the widely varying results from these two types of data offers all the rationale needed by the professional to discard the whole system. One we might term the theoretical (test range) aid, the other is the empirical aid. During long periods of peace where materiel changes substantially, there is often no empirical base to modify the theoretical base. This trend is significant, because of the increasing use of smart weapons on the mechanized battlefield. The era where a long sequence of discrete physical actions had to be accomplished sequentially in the face of enemy fire in order to fire a weapon is beginning to fade. In its place is a new era, where every soldier is computer assisted. This new era is decreasing the difference between test range data and combat performance. Weapons have become less dependent on discrete human manipulation. Sensor technology allows weapons to be fired from a much greater range. The computer chip and the unblinking electronic eye 'steadies the quivering hand'. Whereas the Napoleonic soldier required 200 rounds to inflict a casualty, and the Civil War soldier perhaps 100, today's guided anti-tank weapons require less that two shots to strike an intended victim. As the combat performance of weapons continues to climb towards its test range performance, du Picq's warning will retain less meaning, and the school of moral force will perhaps wane in importance.

At the same time, the improvements in computer technology, artificial intelligence, and expert systems allow much less 'stubby pencil' work to be done within a staff. The ability to weave a seamless digital architecture of useful quantitative decision aids throughout each battlefield function has existed for at least ten years. Yet, we continue to do this work manually.

The Decision Maker

As a general rule, any profession will resist the trend to quantify its approach to decision making, because it encroaches on what makes it a profession--the exercise of educated, specialized judgment. From battle experience and a host of other sources, the military professional forms his own unique set of heuristics. For this reasons, they differ between individuals, units, branches, services and nations. Each individual remembers, and tends to make decisions regarding a particular battlefield function as he last left it.

If something cannot be quantified, it must remain the purview of professional judgment. The OR community's current effort to quantify complex social and psychological battlefield phenomenon through the use of chaos modeling, may meet with a healthy skepticism, and the decision maker will move farther away from OR. If there is no need for the military professional to either trust or need OR, then chances are good he will reject it.

Final Conclusions

Our Army is somewhat schizophrenic on the issue of quantitative decision tools. The two schools of thought--moral and quantitative--are not competitors. They are, in fact, complimentary.

The main requirement for the decision maker and leader is to keep them in balance. Moral force without quantitative means expends itself on the long, exposed march towards Marye's Heights. Quantitative power, without the moral element, quickly abandons its positions in the face of danger and conducts the mother of all retreats. Perhaps the most appropriate approach to balancing the two schools of thought was written by Sir Julian Corbett nearly one hundred years ago:

> That the factors are infinitely varied and difficult to determine is true, but that, it must be remembered, is just what emphasizes the necessity of reaching such firm standpoints as are attainable. The vaguer the problem to be solved, the more resolute must we be in seeking points of departure from which we can begin to lay a course, keeping an eye open for the accidents that will beset us, and being always alive to their deflecting *influences* . . . . By careful collation of past events it becomes clear that certain lines of conduct tend normally to produce certain effects . . . . By pursuing an historical and comparative method we can detect that even the human factor is not quite indeterminable.
>
> We can assert that certain situations will normally produce, whether in ourselves or in our adversaries, certain moral states on which we may calculate. Having determined the normal, we are at once in a stronger position. Any proposal can be compared with it, and we can proceed to discuss clearly the weight of the factors which prompt us to depart from the normal. Every case must be judged on its merits, but without a normal to work from we cannot form any real judgment at all: we can only guess. Every case will assuredly depart from the normal to a greater of less extent, and it is equally certain that the greatest successes in war have been the

> boldest departures from the normal. But for the most part they have been departures made with open eyes by geniuses who could perceive in the accidents of the case a just reason for the departure.[258]

If we cannot come to grips about the appropriate balance between the moral and quantitative schools, the Army will never realize its full combat potential. I do not argue for an adoption of a Soviet-style system of norms. Instead, the rational approach is one where the quantitative school builds the unassailable physical foundation upon which the moral school erects the tactical work of art.

Recommendations

The first step is resolving the conflict within our Army is to again separate Operations Research scientists from Systems Analysis salesmen. Let the Systems Analysts go off into the murky world of materiel marketing. Allow the OR scientists return to the pure mode of enhancing combat operations. If necessary, create tables of organization that call for a tactical OR specialist in each division and corps. Then, provide the OR community with clear guidance to refine FM 101-10-1/2 into a usable tool that contains thoroughly researched quantitative tools for each battlefield function.

The second step is to take FM 101-10-1/2 and create an expert system, run on a laptop computer that eliminates the traditional 'stubby pencil drill' now found in tactical units. This effort should ensure that the resident data bases for systems performance are easily updated with battlefield empirical data.

The third, and most important recommendation, is in leader development. Given the evidence that war is a balance between moral and materiel factors, the type of leader we needed to produce 40 years ago was a 'du Picq with a slide rule'. What we need now is a 'du Picq with a laptop'. The lieutenant of the year 2000 needs to be able to fully exert the traditional leadership abilities which have made American soldiers fight for the last 220 years, but he also must be raised in an institutional atmosphere which encourages the critical application of quantitative decision aids.

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APPENDIX A

MOVEMENT CALCULATIONS

Overview

This Appendix provides an overview of quantitative decision aides that the U.S. Army currently uses to conceptualize and plan unit movements. Additionally, this Appendix will examine a variety of Soviet march calculations. Finally, this Appendix will generate some planning tools to assist the staff officer in estimating march times for a variety of formations.

U.S. Vehicle March Calculations

The ability to conduct surface movement of units and materiel is dependent on several factors. Predominate among these factors is the route structure, which includes variables such as the number of routes, surface type, constrictions, and slopes. Regardless of the desire or need to move quickly, the route structure will determine the upper boundary of how fast a unit can move.

In the absence of an engineer survey of the route structure, FM 101-10-1 suggests the use of the following table to estimate the tonnage carried over a particular route:

TABLE 3

DAILY HIGHWAY TONNAGE FORWARD (STON) AS A FUNCTION OF SURFACE TYPE AND LOCATION

Highway Type	Optimum Dispatch Route	Supply Traffic Communications Zone	Supply Traffic Combat Zone
Concrete	60,000	36,000	8,400
Bituminous	45,000	27,000	7,300
Bitum. Treated	30,000	18,000	5,800
Gravel	10,150	6,090	3,400
Dirt	4,900	2,940	1,600

The daily tonnage predicted in Table 3 is further decremented by the physical conditions of the route:

TABLE 4

REDUCTIONS IN HIGHWAY TONNAGE AS A FUNCTION OF TERRAIN TYPE (IN PERCENT)

Highway Type	Narrow Road (<7.2 meters)	Rolling Terrain	Hills with Curves	Mountainous	Seasonal Bad Weather
Concrete	25	10	30	60	20
Bituminous	25	10	30	60	30
Bit. Treated	25	20	40	65	40
Gravel	25	20	50	70	60
Dirt	25	25	60	80	90

In using Table 4, when more than one reduction is used, FM 101-10-1 suggests that the narrow roadway restriction be applied first, followed by one of the three terrain types. The percentage reduction for bad weather is applied only for periods of sustained inclement weather conditions. Clearly, the ease of movement differs with each of these conditions -- one does not always have the luxury of moving on flat, dry concrete roads. Although the above tables are expressed in throughput tonnage, the same conditions will naturally affect throughput expressed in number of vehicles as well.

The second primary factor impacting on the ability to move is the size of the unit, and the arrangement of the march. Both are taken into consideration during the computation of movement. Instead of listing the detailed movement calculations, which already exist in current U.S. Army publications, this Appendix will instead generate an abbreviated march equation, and then use that equation to generate several nomograms depicting the relationships between number of vehicles, number of routes, distance, and time required to complete the march.

The March Equation

This section generates a simple equation for use in calculating movement times for units of more than 360 vehicles. It's primary use will be in a computer program to generate march times for the case studies in this thesis.

We let N equal the number of vehicles in the formation, and N_r equal the number of routes of march. We then assume that each route will have an equal number of vehicles on it. Additionally, if we assume that an equal number of vehicles is traveling at identical speeds on each route, then the time to complete the entire movement is equal to the time to move along one route. In order to do this, we calculate the number of vehicles on one route (N_{vr}) as:

$$N_{vr} = \frac{N}{N_r}$$

We also know that normal convoys consist of march units (MU), each numbering about 30 vehicles.

Thus, the number of march units, N_{mu}, on one route is

$$N_{mu} = \frac{N_{vr}}{30}$$

Additionally, we know that a normal serial consists of not more than six march units. The number of serials, Ns, is found by dividing the number of march units by 6:

$$N_s = \frac{N_{mu}}{6}$$

Between any two vehicles of the march unit is a vehicle interval (normally 25, 50 or 100 meters. There is a march unit gap (normally expressed in minutes between march units), and a serial gap (also normally expressed in minutes). Let R equal the march rate of the column in kilometers in the hour, and D_{march} represent the distance in kilometers. With these quantities thus defined, we note that the March Time will equal:

$$March\ Time = \frac{D_{march} + D_{vi}(N_{vr} - N_{mu} - N_s - 2)}{R} + T_{mu}(N_{mu} - N_s - 2) + T_s(N_s - 1)$$

Alternatively, in the case of large formations, the formula approaches

$$March\ Time = \frac{D_{march} + D_{vi}(N_{vr} - N_{mu} - N_s)}{R} + T_{mu}(N_{mu} - N_s) + T_s(N_s)$$

Since we know that

$$N_{mu} = \frac{N_{vr}}{30} \quad \text{and} \quad N_s = \frac{N_{mu}}{6}$$

the equation becomes

$$March\ Time = \frac{D_{march} + D_{vi}(N_{vr} - \frac{N_{vr}}{30} - \frac{\frac{N_{vr}}{30}}{6})}{R} + T_{mu}(\frac{N_{vr}}{30} - \frac{\frac{N_{vr}}{30}}{6}) + T_s(\frac{\frac{N_{vr}}{30}}{6})$$

Which reduces to

$$March\ Time = \frac{D_{march} + D_{vi}(N_{vr} x\, 0.961)}{R} + T_{mu}(N_{vr} x\, 0.0278) + T_s(N_{vr} x .00556)$$

Where:

March Time is expressed in hours.

D_{vi} (Vehicle Interval) is expressed in kilometers.

N_{vr} is the total number of vehicles divided by the number of routes (giving vehicles on a single route).

T_{mu} is the march unit gap in hours.

T_s is the serial gap in hours.

Extra Time Allowance (EXTAL) is added to this equation by including one minute for each 25 vehicles in a serial (seven minutes in this model), and then multiplying this by the number of serials on the route, resulting in the final form of the equation, to which we must add time allotted for rest and refueling halts if necessary:

$$March\ Time = \frac{D_{march} + D_{vi}(N_{vr} x\, 0.961)}{R} + T_{mu}(N_{vr} x\, 0.0278) + (T_s + 0.167)(N_{vr} x .00556)$$

Using the final form of the march equation, one can generate a series of march nomograms that provide the tactical decision maker with an accurate estimate of the closure times involved with marches of different sized units, routes, and distances.

March Nomograms

In generating these nomograms, the march rate was set at 32 kilometers in the hour, the vehicle interval set at 100 meters, the march unit interval at two minutes, and the serial interval at five minutes. In these examples, no time has been allotted for either rest stops or refueling.

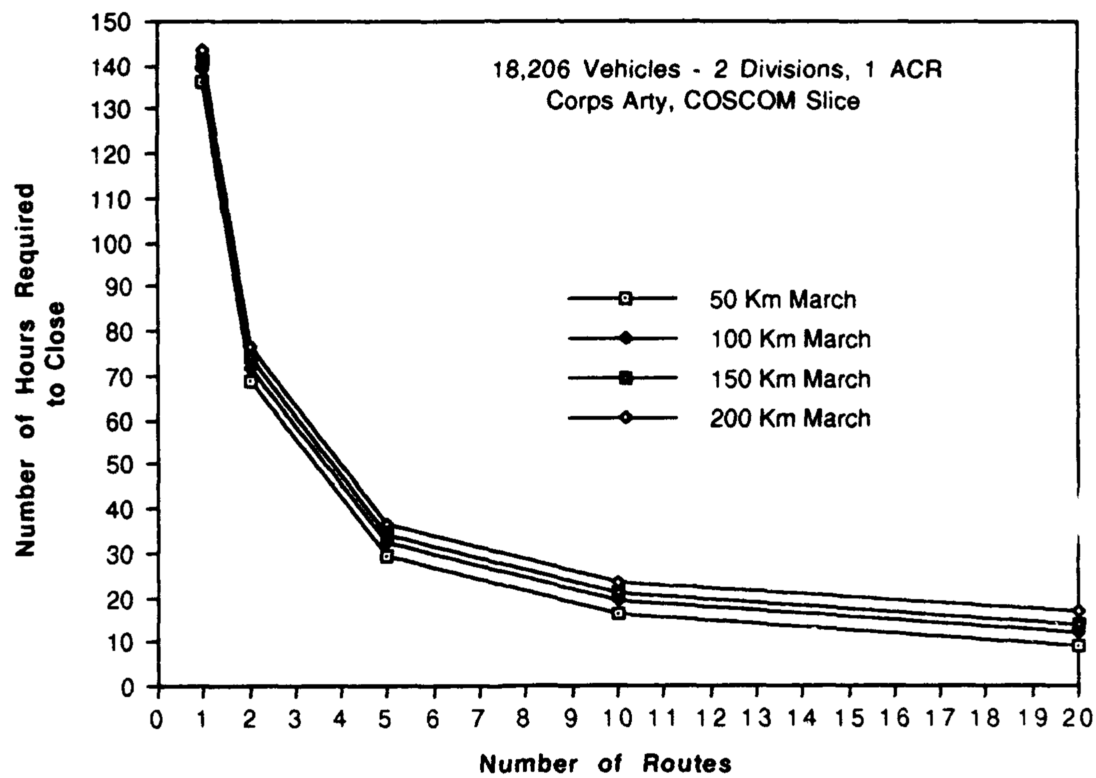

Figure 7. March Time for a Corps as a Function of Number of Vehicles, Number of Routes, and Distance

For the Corps, we note that the main sensitivity lies in the number of usable routes. This is primarily because of the large pass time of the number of vehicles involved.

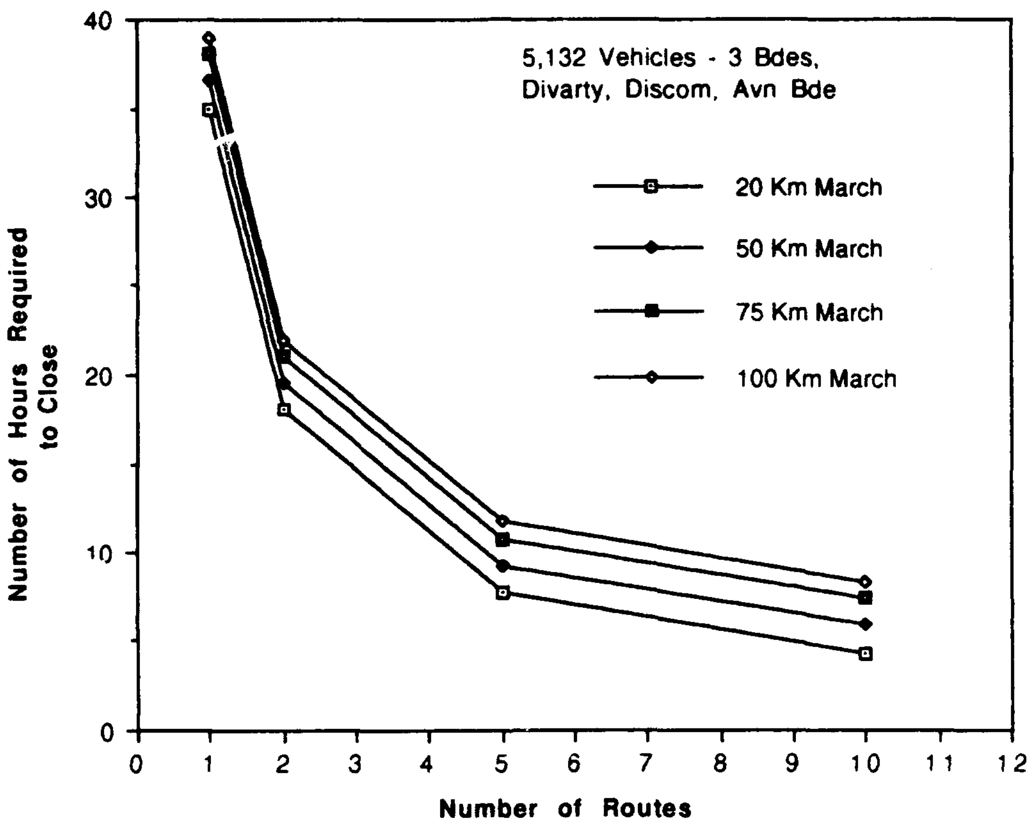

Figure 8. March Time for a Division as a Function of Number of Vehicles, Number of Routes, and Distance

For the division, we note the same sensitivity to the number of routes as the Corps march, due to the pass times involved. However, we also note that the sensitivity to actual distance is increasing.

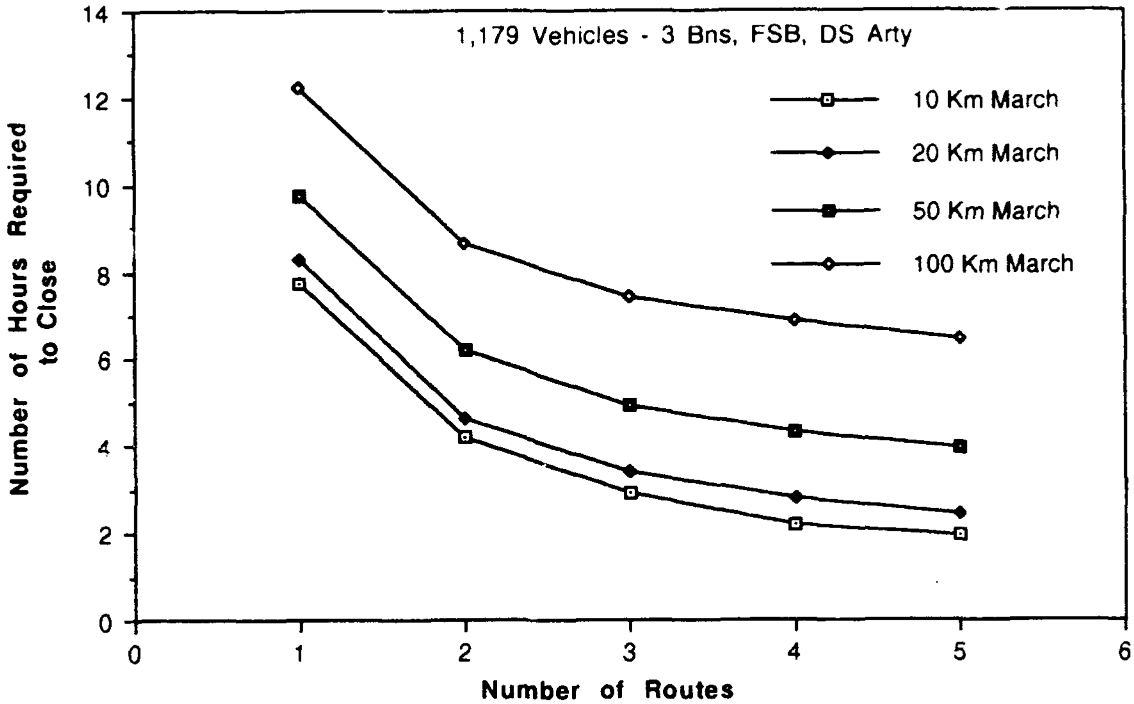

Figure 9. March Time for a Brigade as a Function of Number of Vehicles, Number of Routes, and Distance

For the brigade, we note that the march time is equally sensitive to both the distance and the number of routes used.

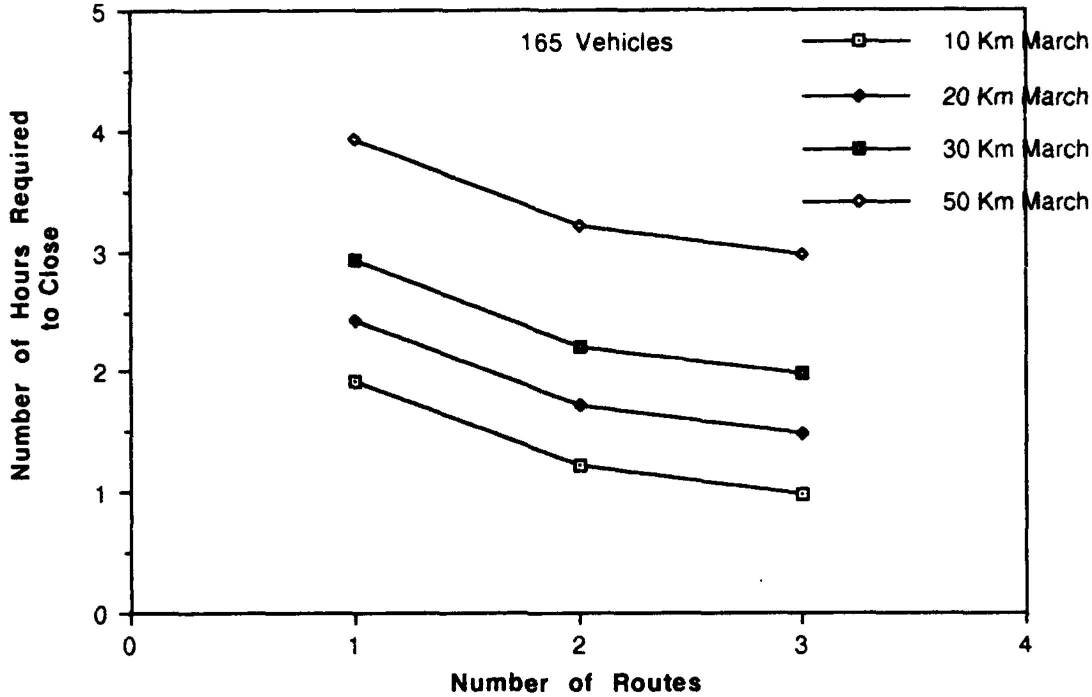

Figure 10. March Time for a Battalion as a Function of Number of Vehicles, Number of Routes, and Distance

For the battalion march, the small pass time involved makes it more sensitive to the distance as opposed to the number of routes. This trend continues through the company and platoon.

Soviet Movement Calculations

Chapter Two described the general Soviet trend of constructing mathematical models for a majority of battlefield functions, and movement is no exception. What follows are excerpts from A. Ya Bayner's Tactical Calculations, a Soviet military text designed to teach young officers the techniques of quantitative decision aids.

March Duration

"This calculation technique is designed for determining the time required for the advancement of subunits from one region to another.

The length of the travel route (from the initial line or point to the closest boundary of the new concentration region), the average travel speed of the route columns, the length of the stops during the movement and the time it takes to pull into the new concentration region, which is calculated when the depth of the concentration region is less than the depth of the route order, serve as the initial data for calculation.

The calculation formula is $t = D / V + t_s + t_e$

where t is the marching time in hours; D is the route length in kilometers; V is the average travel speed of the route columns in kilometers per hour; t_s is the total stopping time during the travel in hours and t_e is the time it takes to pull into the new concentration region in hours." (p.23)

March Length, Average Speed, and Travel Time of Route Columns

"The initial data for the calculation are the number and length of road legs on the route which permit a varying travel speed, the speed on those legs, the depth of the route columns and the concentration region and the stop times of the column during the advancement.

The calculation formulas:

$$D = \sum_{i=1}^{n} l_i \quad ; \quad t_t = \sum_{i=1}^{n} \frac{l_i}{V_i} \quad ; \quad V = D / t_t$$

$$\textit{and} \quad t = t_t + ((d_c - d_r) / (0.6V)) + t_s$$

Where D is the route length in kilometers; l_i is the length of the route legs with varying passability which allow a column travel speed of V_i in kilometers; t_t is the total travel time along the route in hours; V_i is the travel speed on the i leg of the route in kilometers per hour; V is the average travel speed in kilometers per hour; d_c is the depth of the route column in kilometers; d_r is the depth of the concentration region in kilometers; 0.6 is the reduction factor for the travel speed with passage of the columns, which is a function of the conditions and t_s is the total time of stops during the advancement in hours." (pp. 73-74)

Case Study One Computations

For VII Corps, a strength of 65,000 vehicles was used, including a cross-country speed of 10 kilometers in the hour, 100 meters between vehicles, two minutes between march units, five minutes between serials, and a distance of 300 kilometers.

For the Iraqis, a strength of 77,000 vehicles was used, including an assumed road speed of 30 kilometers in the hour, 100 meters between vehicles, two minutes between march units, five minutes between serials, and a distance of 200 kilometers. We know that Iraqi unit discipline broke down during the retreat, and the structure of the Iraqi march in these computations may, in fact, be too slow. The comparison between VII Corps and the Iraqis is shown below in Figure 11:

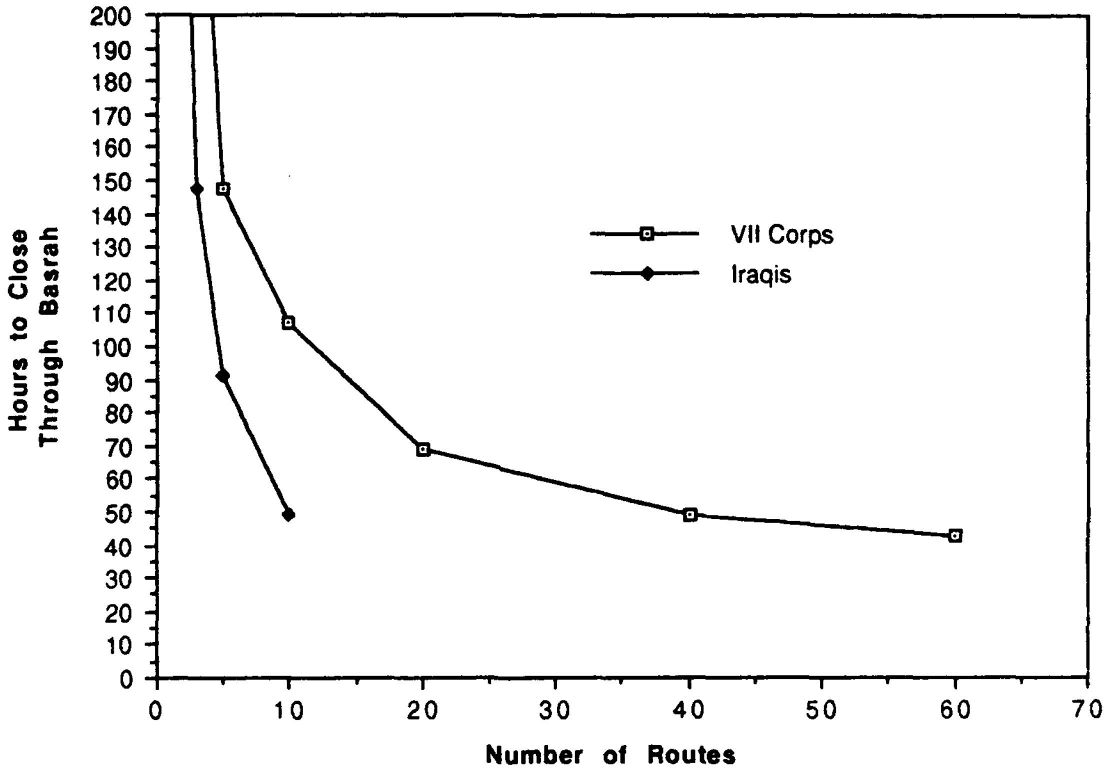

Figure 11. March Times for VII Corps and the Iraqi Army as a Function of Number of Routes

In essence, this graph shows that VII Corps could have completely trapped the bulk of the Iraqi Army only if air interdiction had blocked five or more of the ten escape routes.

APPENDIX B

LOGISTICS CALCULATIONS

Overview

This Appendix provides an overview of quantitative decision aides that the U.S. Army currently uses to conceptualize and plan logistics. Additionally, this Appendix will examine variations of fuel consumption data that impact on operations. Finally, this Appendix will generate some planning tools to assist the staff officer in estimating march times for a variety of formations.

Current Logistics Calculations

In general, the current quantitative tools used to estimate logistics are adequate. FM 101-10-1 grounds the estimation of all supply requirements as a function, or derivation, of the equation:

$$\frac{\text{Number of Items x Consumption Rate per Item x Supply Level (days of supply)}}{2{,}000} = \textit{Short Tons}$$

The manual then concentrates the remaining pages on defining consumption rates for individual pieces of equipment, or units, as a function of class of supply, mission, location and rate of combat.

After calculating the supply requirement, the logistician must determine the road network and transportation assets, based on the mission, required to move the tonnage to the user. As discussed in Appendix A, the ability to move over a road network is estimated in terms of road surface, terrain, and seasonal factors. The transportation assets required to move the short tonnage forward are doctrinally described in terms of either local haul (32 kilometers one way, four trips per day) or line haul (144 kilometers one way, two trips per day). In this case, doctrine tends to obscure a critical phenomenon of surface movement -- the exponential decay of throughput as a function of distance.

Tonnage as a Function of Distance

If one assumes a speed of 32 kilometers per hour, and then begins to increase the distance a truck must travel both ways, the corresponding decrease of tonnage delivered resembles Figure 12 (below):

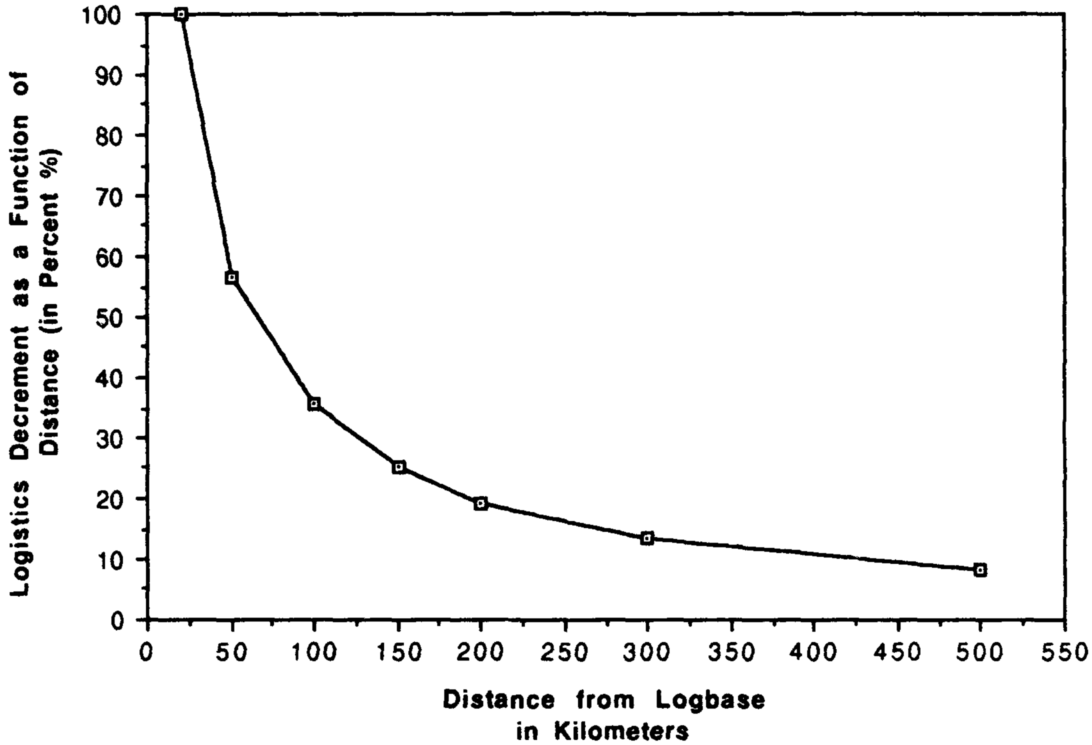

Figure 12. Logistics Decay as a Function of Distance from the Logistics Base

Fuel Consumption Data

A second area where FM 101-10-1 seems incomplete concerns fuel consumption data. Table 2-12 of the manual lists four different consumption rates for each type of vehicle in the current U.S. Army inventory -- idle, average, cross country, and secondary roads. But this table is largely incomplete. Over 90 percent of the vehicles listed have only an 'idle' or 'average' figure in the table. We need to fill in some data concerning fuel consumption in order to adequately address the case studies in this thesis.

The ratio of the fuel consumption estimates for combat vehicles in FM 101-10-1 indicates that, on the average, cross country travel burns about 1.49 times the fuel that travel on secondary roads uses.[1] Tests for the M-60 tank present fuel consumption in the following terms:

TABLE 4

FUEL CONSUMPTION FIGURES FOR THE M-60 TANK

Condition	Consumption	Ratio Normalized to H/S Roads
Idle	1.44 gal/hr	1.3 units/hr
Hard Surfaced Roads	1.1 gal/mi	1 unit/km
Secondary roads	1.78 gal/mi	1.5 units/km
Cross-country with mud	3.06 gal/mi[2]	2.78 units/km

Operators Manuals for W.W.II German tanks reveal the following ranges on a single tank of gas:

TABLE 5

FUEL CONSUMPTION FIGURES FOR GERMAN VEHICLES IN WORLD WAR II

Type	2nd Roads	X-Country	Ratio
Tiger	140km	85km[3]	1.65
Panther	150km	100km[4]	1.5
Mark III	170km	98km	1.7
Mark IV	217km	133km	1.6
SdKfz182	177km	123km	1.4
SdKfz231	275km	183km[5]	1.5

Average Ratio = 1.55

Additionally, combat records show a marked increase between fuel consumption during combat about 1.89 times the estimate for normal cross country travel.[6] In view of these different documented fuel consumption rates, FM 101-10-1 should present fuel figures somewhat in agreement with the following table:

TABLE 6

PROBABLE RATIO OF FUEL CONSUMPTION FIGURES
AS A FUNCTION OF ROUTE CONDITION

Condition	Relative Fuel Consumption
Idle	1.3 units/hr
Hard Surfaced Roads	1 unit/km
Secondary roads	1.5 units/km
Cross-country	2.28 units/km
Cross-country with mud	2.78 units/km
Combat	3.0 units/km

These relative fuel consumption figures represent the increase in consumption due to surface friction only. We also know that one should determine the combine effect of less-than-perfect soils and not-so-level ground on trafficability, since they both combine to form a rough estimate of horsepower (and therefore fuel) required.[7] To even remain in motion, the sum of the power required to overcome soil resistance and the power to move up a slope must not exceed the effective power available to the power train of the vehicle. We know that fuel consumption varies directly with the slope of terrain.[8] A study of tank design parameters shows that to maintain 12 miles per hour on a grade, an armored vehicle must increase its fuel consumption by the following ratios:

TABLE 7

FUEL CONSUMPTION RATIOS FOR VARYING SLOPES

Grade in Percent	Increase in Fuel Consumption
0%	x1
5%	x2.6
10%	x4.4
15%	x6.1

It seems, therefore, a gross oversimplification to publish a small number of fuel consumption figures for each vehicle, when the actual relationship is much more complex.

Logistics Calculations for Case Study Two

Using organizational and technical data contained in the War Department Technical Manual TM-E 30-451, and the user's manuals for both the Tiger and Panther tanks, a fuel consumption table was constructed for Kampfgruppe Peiper. This table shows the gross fuel consumption at idle and during cross-country movement. A similar technique was used to estimate Peiper's fuel consumption for both cross country travel on muddy routes, and combat.

TABLE 8

FUEL CONSUMPTION FIGURES FOR KAMPFGRUPPE PEIPER

Veh. Type	Qty	Idle Fuel Con	Total Idle Fuel	X-Ctry Fuel Con.	Tot X-Ctry Fuel
Pz IV	34	2.05 l/hr	69.7	3.6 l/km	122.4 l/km
Pz V	54	3.99 l/hr	215.5	7 l/km	399 l/km
Halftrack	77	.51 l/hr	39.3	.9 l/km	69.3 l/km
Truck	902	.34 l/hr	306.7	.6 l/km	541.2 l/km
Mtr.Cycle	135	.17 l/hr	22.9	.3 l/km	40.5 l/km
FlakPz	9	2.05 l/hr	18.5	3.6 l/km	32.4 l/km
Asslt Gun	27	2.05 l/hr	55.4	3.6 l/km	97.2 l/km
Mk VI	30	4.05 l/hr	121.5	7.1 l/km	213 l/km
		Total	850 l/hr	Total	1515 l/km

We know that Peiper started with around 175,000 liters in his assembly area at Hallschlag. We also know that he used around 30,000 liters from the 190,000 liter dump he captured in Bullingen. From this, we can construct a fuel consumption diagram for Peiper's march route:

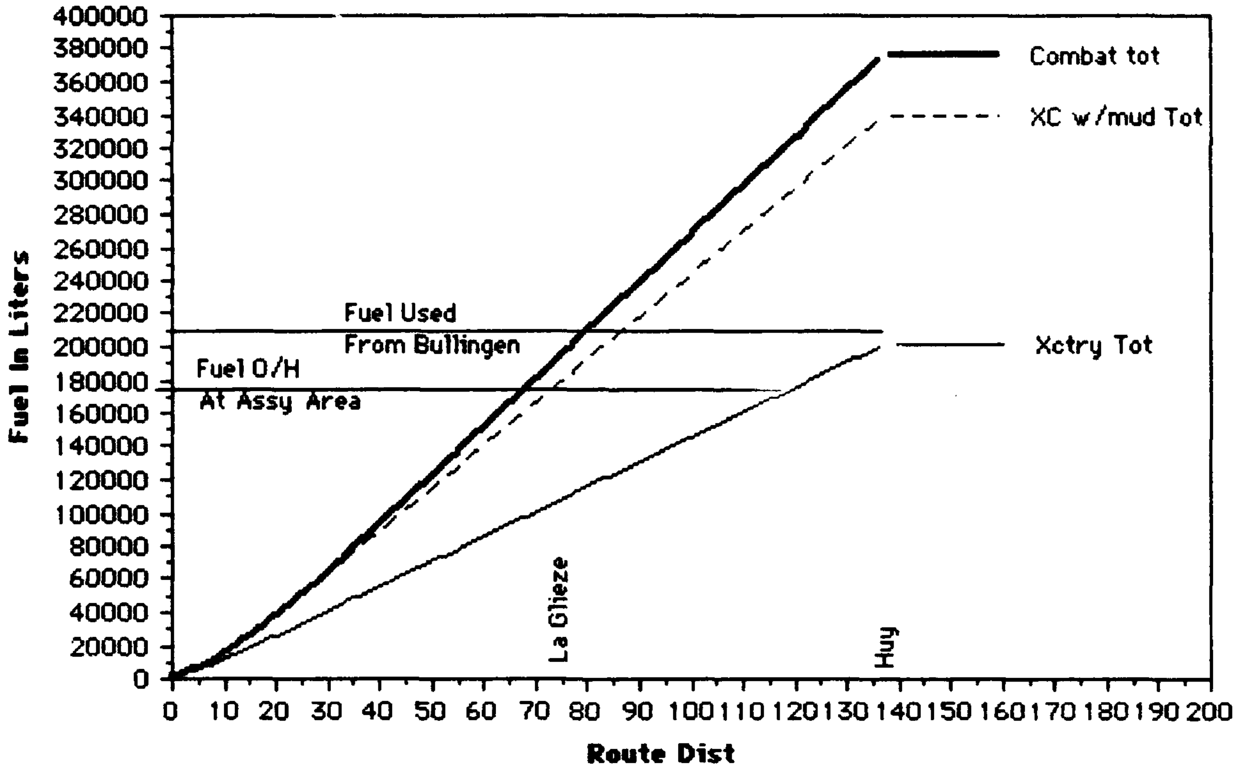

Figure 13. Fuel Consumption Diagram for Peiper's March

NOTES

[1]U.S. Army, FM 101-10-1, Staff Officer's Field Manual: Organizational, Technical and Logistics Data, (Washington, DC: Department of the Army, 1987), pp. 2-21 to 2-52.

[2]U.S. Army Armor Board, Report of U.S. Army Armor Board, Project Nr. 2061, Test of Tank MB, 105mm gun, M-60 (Ft.Monroe, VA: 1960), pp. 68-69.

[3]Inspectorate for Panzer Troops, Tiger-Fibel (Berlin, 1943), p. 6.

[4]Inspectorate for Panzer Troops, Panther-Fibel (Berlin, 1944), p. 30.

[5]U.S. War Department, TM-E 30-145: Handbook on German Military Forces (Washington, DC: U.S. Government Printing Office, 1945), pp. 385-395.

[6]Memorandum, Report of Corps Quatermaster Office, XIX Corps, to Quartermaster, Ninth U.S. Army, Dated 15 December 1944.

[7]CPT Daniel O. Graham, "Soils and Slopes", Armor Magazine (Sep-Oct 1979), pp. 41-44.

[8]M.G. Bekker, Introduction to Terrain-Vehicle Systems (Ann Arbor: The University of Michigan Press, 1969), p. 268.

APPENDIX C

BATTLE OUTCOME CALCULATIONS

Overview

This Appendix provides an overview of quantitative decision aides that the U.S. Army currently uses to conceptualize and plan the allocation of forces to combat missions. Additionally, this Appendix will examine variations of the calculations used unofficially throughout the Army. Finally, this Appendix will develop a simple firepower density model to serve as an alternate decision aide.

CGSC ST 100-9 Model

This model is used to teach Command and General Staff College students the method of force ratio comparison used in the formal tactical decision making process. This model consists of three different groups of subjective numbers; one for the relative value of maneuver units; one for the relative value of artillery units, and one for mission posture. The ST 100-9 model assigns the following subjective values to battalion-sized maneuver units:

TABLE 9

ST100-9 COMBAT POWER VALUES

Type U.S. Bn.	Combat Power	Type Enemy Bn.	Combat Power
Lt. Inf.	0.5		
AASLT Bn.	0.6	AASLT Bn.	0.6
M113A3 Bn.	1.50	BTR Bn.	1.00
M2 Bn.	2.00	BMP 1 Bn.	1.50
		BMP 2 Bn.	1.80
Anti-Armor Bn.	1.00	AT Bn.	1.00
M60A3 Bn.	2.25	T64 Bn.	1.45
M1 Bn.	3.00	T72 Bn.	1.20
M1A1 Bn.	3.15	T80 Bn.	1.56
AH-64 Bn.	4.00	HIND Bn.	3.00

The ST 100-9 model then totals the combat power for both sides in terms of maneuver and artillery strength. If necessary, the combat power of the defensive unit is multiplied by a factor that provides a relative advantage according to the time spent on preparing the defense. The final numbers are then compared to determine the final force ratio.

Theater Analysis Model

The computerized Theater Analysis Model (TAM) is used at the Joint level to determine force ratios in theater war games. It uses more detail than the ST 100-9 model in that it calculates combat power by subjectively assigning relative values to each individual system, and then grouping these totals into five categories: armor systems, anti-tank systems, artillery systems, infantry systems, and air defense systems. TAM multiplies these combat power totals first by a mission factor, and then a terrain factor to generate an overall combat power score for each side.

The NTC Model

The NTC Model uses a killer-victim database to assign historically correct combat values to each individual system in an exercise. These individual combat values are then totaled to provide relative combat power ratios. Of the models described so far in this Appendix, the NTC model is the only one with an empirical approach. However, the killer-victim data base used in the NTC model is largely the product of the Multiple Integrated Laser Engagement (MILES) system used to simulate direct-fire combat. How accurate this data transfers to the real battlefield has yet to be determined.

Developing a Firepower Model

Each of the combat power models discussed so far are rather static in nature, and they inadequately address a variety of tactical variables. In developing a firepower model, we are searching for a purposeful, predictive representation of combat phenomena. The model does not have to be a complete representation of combat, but it should include the essential variables that produce firepower. The essential variables of firepower should include at least four qualities: the ability to see a target, the ability to hit a target over distance, the ability of a hit to subsequently kill a target, and the rapidity with which all these activities can be performed. In order to develop the firepower model, we will examine the relationship between the four qualities of firepower between two different weapons systems -- an M-60A1 tank and a Tube-launched, Optically-tracked, Wire-guided (TOW) anti-tank missile system.

Weapons Performance

The M-60 tank is a direct line-of-sight weapon system. Its daylight sight enables it to engage targets out to perhaps 3,000 meters. The probability of it hitting its target varies with the range of the target. The TOW missile system has similar optics, but the missile is guided--with relatively constant accuracy--out to the maximum effective range of the system. The probability of either system hitting its target as a function of range is depicted below in Figure 14:

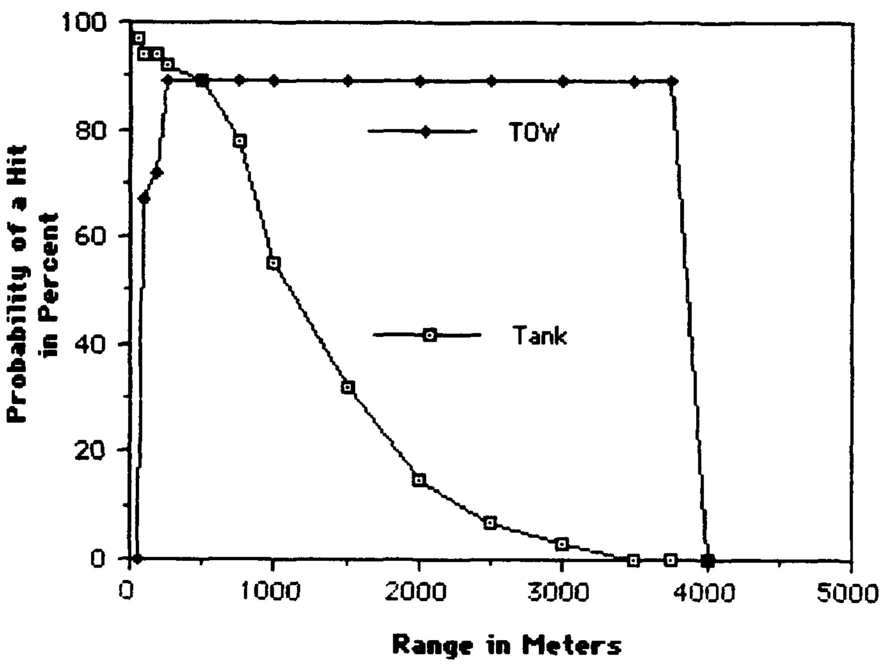

Figure 14. Probability of Hit Data for the M-60A1 tank and the TOW Missile system.

In order to simplify the model, we will assume that if either system hits its target, the target will be destroyed. Additionally, we will assume that an M-60 tank can fire at a sustained rate of six rounds per minute, and the TOW can fire at a sustained rate of two rounds per minute. At this point, the characteristics of each weapon are developed fully enough to construct a simple fire power model.

The Scenario

In our notional scenario, the blue force -- a tank regiment equipped with 90 M-60A1 tanks-- is attacking a red battalion equipped with 30 TOW systems. The terrain is flat and open, and it is noon on a clear day. At this point, we can begin to 'lump', or aggregate, certain weapons characteristics together to generate a notion of fire density. For the tank regiment, we can do the following:

$$90\ Tanks \quad x \quad 6\ Rounds / \min \quad x \quad accuracy = Density$$

A similar equation 'lumps' the TOW battalion's characteristics together. Since the accuracies of either weapon changes over range, the density should reflect that fact. When graphed, the opposing fire densities look like the Figure 15 (below):

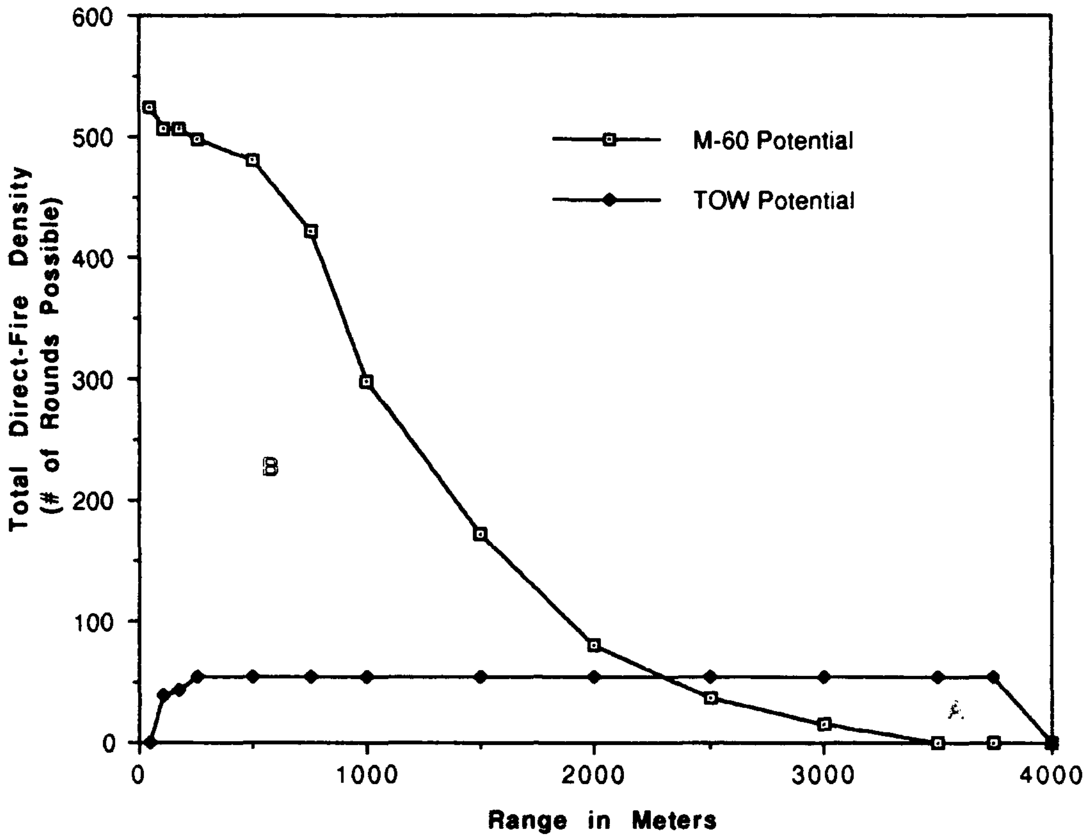

Figure 15. Fire Densities Per Minute as a Function of Range

This graph represents the maximum density of fire that can be expected out of either unit in this scenario. Other factors may reduce these densities, but nothing can increase them.

Of particular interest in this model are the two areas A and B noted in Figure C-2. Area A represents a battlefield condition most favorable to the TOW battalion, as it capitalizes on the technology inherent in the weapon. Quite reasonably, the TOW battalion commander would want to keep the battle confined to area A. Area B represents a battlefield condition most favorable to the M-60 regiment, as it is here that the rapid direct fire of the tank can have its greatest effect. We would expect the tank regiment commander to try and fight the battle in area B as much as possible.

Transition Mechanisms

In this scenario, each commander desires to fight in a particular condition that maximizes the characteristics of his unit and creates the greatest density of fire. The tank regiment commander will try to find some tactical method to quickly transition from area A to area B and gain an advantage. The TOW commander will try and keep the battle in area A as long as possible. In essence, one commander is searching for a transition mechanism (or mechanisms) to change the conditions of the battle, and the other commander is going to try to deny those mechanisms to the enemy.

The mechanisms available to the tank regiment include traditional methods such as suppression, speed, surprise, mass, choice of routes or time of day, and smoke. He may have technological mechanisms, such as missile guidance jammers. The TOW battalion must find the appropriate counter to each of these transition mechanisms in order to win the battle, such as security, obstacles, or camouflage. In essence, the result of this fight is dependent upon the struggle over the transition mechanism.

The Transition Mechanism model does not predict victory. Rather it attempts to points out where lopsided fire densities exists, and it prompts the commander to search for methods to avoid disadvantage.

APPENDIX D

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